AIR FORCE SPACE COMMAND

Volume 2, Number 2

HIGH FRONTIER

THE JOURNAL FOR SPACE & MISSILE PROFESSIONALS

SPACE ACQUISITION: Past, Present and Future

Headquarters
Air Force Space Command
Peterson Air Force Base, Colorado

Commander
General Lance W. Lord

Director of Public Affairs
Lt Col Marcella Adams

Creative Editor
Ms. Nadine Sage

High Frontier Staff

Lt Col Kent Dalton
Mr. Masao Doi
Maj Corvin Connolly
1Lt Robert Crawford
1Lt Jennifer Whitaker
TSgt Kate Rust
TSgt Jennifer Thibault

Published by a private firm in no way connected with the US Air Force, under exclusive written contract with Air Force Space Command. This command funded Air Force journal is an authorized publication for members of the United States military Services. Contents of *High Frontier* are not necessarily the official views of, or endorsed by, the US Government, the Department of Defense, or the Department of the Air Force.

Editorial content is edited, prepared, and provided by the Public Affairs Office of Air Force Space Command. All photographs are Air Force photographs unless otherwise indicated.

High Frontier, Air Force Space Command's premier space professional journal, will be published quarterly. The journal provides a scholarly forum for professionals to exchange knowledge and ideas on space-related issues throughout the space community. The journal focuses primarily on Air Force and DoD space programs; however, the *High Frontier* staff welcomes submissions from within the space community. Comments, inquiries and article submissions should be sent to AFSPC.PAI@peterson.af.mil. They can also be mailed to:

AFSPC/PAI
150 Vandenberg St. Ste 1105
Peterson AFB, CO 80914
Telephone: (719) 554-3523
Fax: (719) 554-6013

For more information on space professional development visit:
http://www.peterson.af.mil/spacepro

To subscribe: nsage@colsa.com

COVER: Air Force Space Command faces the challenge producing innovative, affordable, operationally effective space systems. We must continue to transform space acquisitions into a more efficient and product-driven process that can successfully meet the warfighting needs of today and the future.

Photo credits: Lockheed Martin and United States Air Force

HIGH FRONTIER

The Journal for Space & Missile Professionals

Volume 2, Number 2

Contents

Next Issue: ***Space Command and Control (C2)***

Introduction

People, Process and Partnerships... Our Keys to Acquisition Success!

General Lance W. Lord
Commander, Air Force Space Command

"Not a single program missed its target date of reaching operational capability. Of course there were concerns, but we met them every time." - General "Bennie" Schriever

If something is worth doing, it's worth doing right. That's why in June of 2005, we set out a marker for space acquisition. My challenge to the 40,000 men and women of Air Force Space Command (AFSPC) was to become the Department of Defense (DoD) model for acquisition excellence. In this issue of the High Frontier we continue the dialogue aimed at leading us toward that goal. You may be surprised to find several articles critical of AFSPC, Air Force, and DoD acquisition practices. The goal of this issue is not to ignore challenges and play up success stories. Our goal is to expand the dialogue on space acquisition and solidify ways in which we can work together to reach the next level of excellence.

Recently our Chief of Staff, General "Buzz" Moseley laid out his top three priorities for the Air Force.

1. *Maintaining a laser sharp focus on the Global War on Terror*
2. *Developing our people*
3. *Recapitalizing the aging Air and Space Fleet*

In many ways, this last priority may prove to be our most difficult challenge. It will take time to restore credibility and recapitalize the space fleet, but it must be done. The first step is to continue an open and honest discussion on all the issues.

Voices on all sides of the acquisition discussion are in complete agreement on one thing—the space capabilities currently under development are vital to the continued success of joint and coalition warfighters. Our legacy systems have transformed the modern battlefield and given us an asymmetric advantage. It will require a total team effort to maintain that advantage. It will also require us to push ahead with our space professional development strategy, solidify our acquisition processes, and partner not only across AFSPC, but with industry leaders and joint warfighters throughout the DoD. Our focus on *"People, Process, and Partnerships"*...what we call the "3 Ps" to success, is instrumental to space acquisition excellence.

People are the foundation for success in everything we do. Without trained, equipped and motivated professionals, even our most sophisticated space and missile systems are useless. We have the blue suit, contractor, and civilian expertise needed to establish space acquisition as the DoD model. However, the challenge lies in balancing that talent across the National Security Space enterprise. It is essential for us to leverage our human capital across DoD, national, civil and commercial space communities so we maximize the performance of our Nation's space capabilities. We have reached out to our partners in the space acquisition business and we jointly recognize the need to share the limited pool of acquisition talent as we take on the programmatic challenges across our organizations.

Our Space Professional Development Team has completed much of the hard work needed to inventory the capabilities of our space professionals and the requirements of each space billet. While there is still work to be done, our efforts have been praised by a host of senior leaders and the Government Accountability Office (GAO). In upcoming assignment cycles, we will use the information we have compiled to execute our strategy—putting the right people in the right places at the right time to achieve mission success and develop each of our space professionals. For some of our finest space warriors, the right place will be the Space and Missile Systems Center to serve as a member of our space and missile acquisition team.

We must also find ways to retain and promote our best and brightest leaders in the acquisition business. If we are serious about turning the corner and getting our acquisition house in order, we must bring our people with us. This means providing command billets, deployment experiences, and advanced education opportunities in greater numbers.

In addition, it is absolutely essential that we develop the critical skillsets our people need to succeed. The acquisition reform errors of the 1990s left us with a severe lack of expertise in cost estimating, system engineering, and program management...especially across our mid-career workforce. Many in Congress, industry, and throughout the DoD have recognized these deficiencies. Since the 2001 Space Commission Report, we have worked with The Aerospace Corporation to develop rigorous classroom training. The National Security Space Institute through its Space 100-300 courses has begun to stabilize the knowledge base across the entire space arena. Finally, the Space Acquisition School we developed gets us back to the basics our acquisition pioneers, like General Schriever, were so successful with during the Cold War.

Well begun is half done.
- Aristotle

If people are the foundation, **processes** form our recipe for success. In the space business, the recipe is outlined in National Security Space Policy (NSSP) 03-01. As the Young Panel pointed out, we had allowed cost to replace mission success as our number-one priority. NSSP 03-01 provides us a course correction reaffirming our commitment to mission success. As you will read in this issue of *High Frontier,* it also realigns programs for earlier reviews and defines key Milestone Decision Authority timelines to gain better control of the acquisition process early in the program lifecycle. Finally, NSSP 03-01 mandates the use of independent reviews to enhance our insight into all programs, and establishes more rigorous standards for our use of immature technologies.

When attempts to push for major advancements in technology do not materialize, excessive program delays occur. We have allowed too much technology development to creep into acquisition programs, which has resulted in instability. We have the solution. Resources for technology development must be part of a more robust research and development (R&D) effort and protected as one of the key foundations for program success. That said, the R&D budget should not be seen as a savings account for over-budget programs or a slush fund to be tapped for pet projects.

The changes we have made so far to the acquisition process have us postured for success. However, having the recipe is not nearly enough. We must take the next step to foster a culture of accountability and performance. In this effort, it is important to understand that "metrics matter." We must be able to define success and measure it. On the battlefield, we can easily measure the performance of the capabilities provided through the Global Positioning System or Military Satellite Communication. We need to do the same as we develop the next generation space capabilities. We must know where, when and how we are succeeding…and failing. Ultimately, each of us must be accountable for our results.

Joint warfighters only get the correct capabilities when the entire National Security Space team works hand-in-hand to develop, field and operate the systems they need. **Partnerships** are the final building block we are using to develop and field cutting-edge space and missile capabilities. In my mind, the need has never been greater to partner as we take on the space acquisition challenges ahead.

As we push forward, we must become more horizontally integrated across the space community and DoD. There are many stakeholders within the space community—AFSPC, National Reconnaissance Office, Combatant Commands, Air Staff, the R&D community and industry. Our challenge is to operate on the same page with a common set of priorities. Today's fiscal environment simply will not allow disparate efforts that duplicate services or cause gaps in capabilities. The formula for success in the National Security Space enterprise is simple: *Mission success equals joint warfighter success.*

One of our most valuable partnerships is with the The Aerospace Cooperation. The Aerospace team makes up about 25 percent of our total acquisition workforce and provides much of the engineering expertise we rely on day to day. Clearly, our Aerospace partnership and their ability to rise to the occasion has been vital in helping us turn the corner in space acquisition.

General Lance W. Lord (BS, Otterbein College; MS, University of North Dakota) is the Commander of Air Force Space Command, Peterson AFB, Colorado. General Lord is responsible for the development, acquisition and operation of Air Force space and missile systems. The general overseas a global network of satellite command and control, communications, missile warning and launch facilities, and ensures the combat readiness of America's Intercontinental Ballistic Missile (ICBM) force. The general has commanded two ICBM wings and a space launch wing and served as the Commandant of Squadron Officer School and Commander of Air University. Prior to his current position, General Lord was the Assistant Vice Chief of Staff for Headquarters US Air Force. The general is also a graduate of Squadron Officer School, Air War College and a distinguished graduate from Air Command and Staff College.

The challenges we face have been around for longer than many of us realize. We are not the only ones who have wrestled with the best way to acquire military systems. In fact, we have faced issues with acquiring high quality products on time and on budget since the days of George Washington. In the last 200 years, more than 900 GAO reports, a dozen major commissions, and 4,000 studies have set their sights on the topic of military systems acquisition. Without question, we are dealing with an exacting and arduous issue.

However, the time for the blame game is over. It is time for us to partner across a multitude of organizations and disciplines to rebuild our credibility with senior DoD leadership, Congress and ultimately the American taxpayers. We have a proud history of success, as evidenced by the support our on-orbit assets currently provide joint warfighters and national intelligence users.

When General Schriever was building the foundation for our modern Space and Missile Force, he took pride in setting the standard for integrity. In all the systems he championed, never once was the program's management questioned. His team was beyond reproach. Routinely, programs achieved operational capability on time or well ahead of schedule. The partnerships he forged with industry and across the DoD were the key weapon in General Schriever's arsenal. Just as General Schriever did during the Cold War, no matter what we define as mission success in our areas of interest, we must deliver. We have experienced breaches in nearly every major acquisition program and these breaches are unacceptable.

The good news is we have the recipe for success and we have identified and targeted our weak areas. We are about to turn the corner, but we must keep up the pace for long-term success. Our worst case scenario should be on time and on budget performance. This means we must work together to routinely deliver programs early and under-budget. The only thing we can do as a team to rebuild our acquisition credibility is to reshape the way we deliver space systems. It's a matter of focused, deliberate execution.

For us that translates into developing the capabilities of our people, following our processes, and partnering across the space community, DoD, and industry. I'm convinced we are on course to be the DoD model for acquisition excellence. Our challenge will come in maintaining our determination to take AFSPC and the members of the National Security Space enterprise to the next level of excellence.

Senior Level Perspective

Military Space Acquisition: Back to the Future

Lt General Michael A. Hamel
Commander, Space and Missile Systems Center
Los Angeles AFB, California

Space has played a key role in military planning and operations for half a century. General Bernard A. Schriever and a small band of Air Force officers established the Western Development Division in Inglewood, California in 1954, and created an amazing array of military space systems and capabilities that have served us through the Cold War, peacetime, world crises, major conflicts and now, the Global War on Terror. Today, space is an indispensable element of joint military operations, employed in virtually every aspect of air, land, maritime and special operations. But, if you read defense press articles on military space, you might conclude all space programs are broken, overrun and late to need. Yet, step inside a Joint Task Force command center, an Army Tactical Operations Center or Joint Air Operations Center and ask our joint warfighter 'customers' for their views and you would probably receive a much different perspective. We have the healthiest constellations of military satellites in decades—including the Defense Support Program, Military Satellite Communications (MILSATCOM—DSCS, MILSTAR, GBS), Global Positioning System (GPS), and Defense Meteorological Support Program and a host of classified space systems. Likewise, we have developed an entire new generation of modern launch systems, Atlas V and Delta IV. Our on-orbit and terrestrial command and control network systems are robust, and in high demand, providing critical space capability to execute military and civil operations in every theater across the globe. In fact, many of these systems are vital to friends, Allies, and other international users, enabling a better quality of life for millions globally.

Reality Check

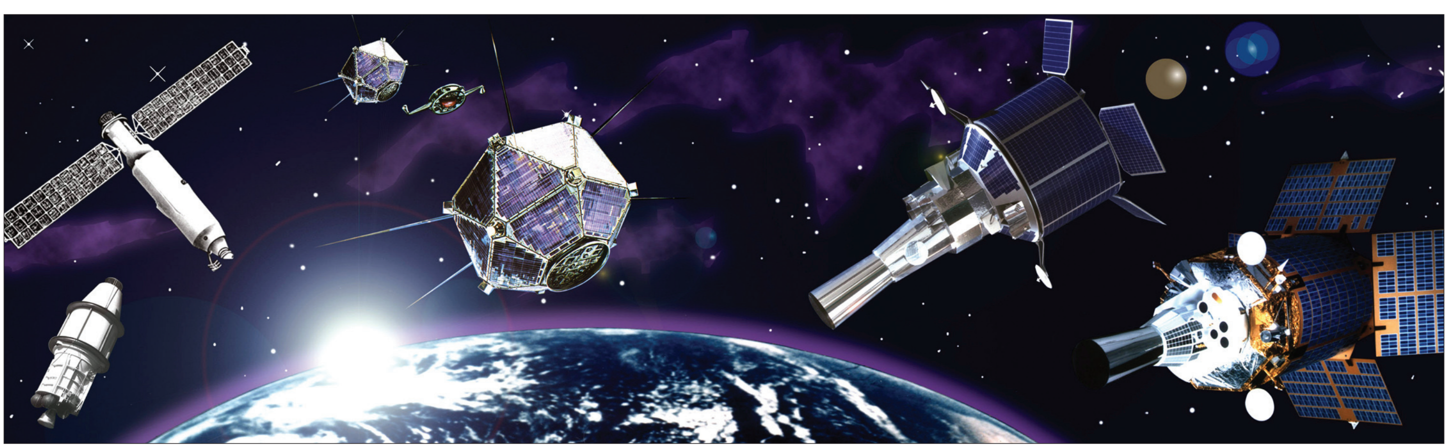
So where is the truth, how do we reconcile the outstanding military space forces we have today, with the problems we face developing and fielding new space capabilities to meet the growing needs for ever more capable space systems to deal with the threats and security needs in the future? This is not some abstract or academic question—it is one of the key issues facing our Nation and military in an increasingly unpredictable world, with ever greater global interdependency and complex national security interests. Space is a key enabler of global, precision, and joint expeditionary operations—it provides unprecedented speed, lethality, and decision superiority across the battlefield. Closing the gap between what we have and what we need in military space is a critical challenge for Air Force Space Command (AFSPC) and the Space and Missile Systems Center (SMC) as we look forward into the next half century of military space power development.

From where I sit, dual-hatted as both the Air Force's Program Executive Officer (PEO) for Space and Commander of SMC, most of the challenges we are facing in developing and fielding a whole new generation of space systems are being driven by the transformation of the Nation's military force. These problems include schedule slips, cost growth beyond original estimates, engineering deficiencies and design flaws, inexperienced program managers, and inadequate program reserves to deal with inevitable development problems and changes.

Looking Back

It is important to understand past space acquisition successes and the lessons of recent history if we are to propel our current programs on track and lay the foundation for future successes. In the early 1990s, the Cold War ended, defense budgets were cut, and our Nation reaped a "peace dividend." This drove significant reductions in military weapons systems development and reductions in both military force strength and defense industry downsizing. The Air Force systemically cut back its development and acquisition workforce and delayed its recapitalization plans.

To square the increasing need for space capabilities with the



reduced defense budgets, new concepts for acquisition management were introduced. Acquisition reform initiatives were born in 1994, and the responsibility for program management was largely shifted to, and shouldered by, the defense industry. The construct was known as Total System Performance Responsibility, wherein industry was expected to deliver end-to-end systems. Defense contractors were given broad authority to interpret performance requirements, define system designs, establish statements of work and deliverable items, and use commercial "best practices." Government involvement was minimal, managing only top-level systems performance, cost and contractual terms. The government became little more than passive observers in the developmental process, and the acquisition mindset was one in which the "contractor was in charge." Good people still performed their assigned tasks to the best of their ability, but the rules of engagement and budgeting priorities had changed.

Less governmental oversight led to less contractor attention and the initial cost savings of streamlining and manpower reductions quickly became cost overruns, performance shortfalls, and increased risks. System Program Office leadership did not have full insight into contractor work, decisions and program risks, and contractors were increasingly incentivized by short-term fee plans. Concurrently, major growth in commercial space investments and industry in the mid to late 1990's led to a mindset that the government could simply become a customer of a robust commercial industry base, rather than an active manager in a specialized defense industry. This led to acceptance of major risks and unrealistic cost estimates for a number of satellite and launch system programs. The government delegated significant authorities to industry without maintaining sufficient oversight to ensure success. Lack of process controls and active government oversight directly impacted mission assurance as evidenced by the series of costly launch failures in the late 1990s. Further, they hoped for a boom in commercial space investment, which did not materialize and a number of high profile commercial developments collapsed. A fundamental failure of acquisition reform was that while the government could assign maximum responsibility to industry, it could not delegate accountability for the success of these increasingly critical military space capabilities.

The workforce charged with developing, acquiring, fielding, and sustaining our military space systems is in a state of flux, which points out systemic changes and challenges. In 1992, SMC had approximately 6,500 government, Federally Funded Research and Development Center (FFRDC), and Systems Engineering and Technical Assistance (SETA) contractors actively engaged in the center's 16 major space programs. In 2005, with 32 percent fewer people (roughly 4,500 today), we are managing 31 major programs, involving recapitalization of every mission area, replacing legacy systems with impressive new technologies. The sheer number of new developments are compounded by the complexity of these systems, which must be horizontally integrated into system-of-systems capabilities and a myriad of joint applications. The demographics of the workforce also presents challenges. Currently, 65 percent of the civilian workforce is retirement-eligible, junior military officers

EUVE Launched 7 June 1992.

comprise a disproportionate share of the workforce and shoulder program management challenges well beyond their experience levels, our mid-grade officer program manning is less than 60 percent of our current authorization and Congressional ceilings on FFRDC and SETA assistance are capped. Clearly, recovering from acquisition reform initiatives and severely a reduced acquisition workforce and experience base demands bold leadership, and organizational and cultural change.

Commission Review, Findings

The series of space launch failures in 1998 and 1999, which cost the Nation over $11 billion, was a wake-up call for the Air Force. A number of studies, reviews, commissions, and panels were instrumental in identifying causes and corrective actions. The Launch Broad Area Reviews examined the launch failures and made recommendations for changes in procedures, practices, and operations. The 2001 Space Commission report recommended the following initiatives: the President establish space as a National priority; the Air Force be designated the Department of Defense (DoD) Executive Agent for Space; and a Major Force Program for Space be established to manage all space programs and resources across the DoD. It further recommended alignment of the Air Force and National Reconnaissance Office (NRO) space programs under a single senior official, appointment of the Air Force under secretary as the DoD Acquisition Executive for Space and realignment of SMC from Air Force Materiel Command to AFSPC to better integrate space development and operations organizations under a single Air Force four star commander.

Another key study, chartered by the Defense Science Board and Air Force Science Advisory Board, was chaired by former NASA Goddard Space Flight Center and Lockheed-Martin senior executive Mr. A. Thomas Young. The "Young Panel" took a comprehensive look at national security space acquisition problems. They examined Air Force and NRO space acquisition systems, practices and budgeting processes, and recommended a roadmap for course correction. The panel keyed on three major space programs: the Evolved Expendable Launch Vehicle program, the Space Based Infrared Systems High missile warning/defense satellites, and the Future Imagery Architecture intelligence satellites. It also looked at the GPS, Space Based Radar (SBR) and MILSATCOM programs. The panel's major findings consisted of the following: cost had become a higher priority than mission success, unrealistic estimates led to unrealistic budgets and unexecutable programs; there was a lack of discipline in system requirements; the government's space acquisition capabilities were seriously eroded and finally, industry failed to implement proven management and engineering practices. The panel also reached conclusions and made recommendations on a number of issues from reestablishing engineering discipline to assuring adequate program reserves to ensure successful delivery. The Young Panel and other reviews provided the compelling assessment, call to action and practical remedies for the serious deficiencies in our military space development and acquisition processes.

"Back to Basics" in Space Acquisition

We took these collective recommendations and have worked to implement a broad plan of action to address the root problems identified in the reviews and panels. In addition to these studies, SMC and The Aerospace Corporation also conducted detailed analysis on testing in launch vehicle and satellite programs, growing quality problems in components and subsystems, and increasing system complexity, especially in the area of software development. These comprehensive fixes include reestablishing systems engineering discipline, critical development processes, tailored military specifications and standards, cost estimating capabilities, cost/schedule management and senior technical and program management reviews—processes and practices that have been proven over decades.

Our top-level acquisition policies and procedures are now institutionalized through National Security Space Acquisition Policy Directive 03-01, which provides tailored space acquisition review and "best practice" guidelines. It institutes a Defense Space Acquisition Board, which uses Independent Program Assessments for in-depth review of technical and program status at key decision points with increased emphasis on technical baselines, cost estimates, and risk assessments. SMC holds weekly SMC Program Management Reviews where each Materiel Wing or Group Commander drills down into details on technical status, program issues, schedule challenges, and cost performance. These reviews ensure every major program is assessed in detail at the PEO level on a quarterly basis. We also hold regular Executive Committee meetings with senior industry executives to focus on particular programs and conduct Benchmarking Reviews with the major aerospace companies to provide frank feedback and develop stronger teamwork.

There's increased collaboration between government and industry to emphasize systems engineering, process control, and better management practices. A Space Quality Improvement Council, led by The Aerospace Corporation, brings key government and space industry leaders together to collaboratively improve specifications/standards; parts, materials, and processes; test and evaluation; software development; systems engineering and subcontractor/vendor management.

Key to all these improvements though is reinvigorating the workforce by recruiting top new talent, filling authorized positions with appropriate grade/experience, incentivizing retention, streamlining hiring practices, providing advanced training and education, and revitalizing mentoring efforts. Workforce initiatives for our military, civil service, FFRDC and SETA contractors seek to reestablish key skills in engineering, cost estimating, contracting, and program management; increase workforce stability and tenure; improve pay and benefits, and raise Congressional ceilings on FFRDC's and SETA contractors.

Continual Improvement

As part of "getting back to basics," we are reemphasizing proven principles for success across the space acquisition business. From our most senior Materiel Wing Commanders, to our young project officers, to our seasoned principal engineers with The Aerospace Corporation, we are re-instilling a sense of personal accountability – the idea that each individual "owns" a particular system, product, process, or deliverable. In a business where you don't get a second chance to do it right, we need a rigorous system of checks and balances. There is no better way to assure mission success than to have everyone on the team feel personal accountability and cross-check every detail—we apply this concept across the board.

We also must better understand requirements, technical and program baselines and what it will cost to produce the desired capability. Program stability is essential if we are to avoid continuous re-planning and re-baselining, which inevitably causes delays and cost growth. The government must have the ability to accurately estimate costs and protect critical cost, schedule and performance reserves if it is to deliver what it promises. As acquirers, we must provide accurate assessments to senior decision-makers and Congressional members, linking costs, risks, and consequences. Likewise, we owe the operational decision makers honest feedback on the implementation and development risks, which ensue from the needs and details in requirements documents. In the end, Materiel Wings and Groups have the accountability to the taxpayers and it is essential we not over-commit if we do not have the necessary resources to deliver the desired capability. This said, even if we produce the greatest systems in the world, it's insufficient if we are simply delivering individual, stove-piped programs to the field. We must provide integrated mission solutions, which means we have to look across the space enterprise and ensure all the individual systems fit into an overall space architecture that delivers operational capabilities in an integrated fashion to our customers.

Finally, we cannot sustain improvement unless we can measure how we are progressing. Metrics are a critical part of restoring predictability and continuous improvement. Getting measurable progress points in terms of performance, design, testing, and delivery of satellite systems is key.

Prognosis

It has been questioned whether we have "lost the recipe" in space acquisition. The real answer is, "No, we didn't lose the recipe; we just stopped following it for awhile." The efforts we are taking to rebuild the acquisition workforce, processes and discipline will produce the systems we've come to depend upon. We know how to do it—we just have to get back to following the recipe. At the same time, the reality is a number of our programs were flawed from inception and you can not 'unflaw' a program five years after its start. We have the dual challenge of restoring technical rigor in programs well into manufacturing, assembly and test, while at the same time implementing proven technical and management practices and discipline in new programs. We've made a lot of progress in achieving this goal of delivering what we promise. Under Secretary of the Air Force Dr. Ronald M. Sega is providing new vision and leadership for evolutionary, incremental development of new military space capabilities and our AFSPC Commander, General Lance W. Lord, has challenged SMC to become the recognized DoD Center of Excellence for Acquisition—a challenge we are vigorously taking on. It will likely take several years for SMC to fully achieve this goal, but we are making solid progress and believe we will "turn the corner" in 2006. We must regain the trust of the American public, Congress and the Joint warfighter.

"Keep Going, Keep Going"

As the "Birthplace of Military Space," SMC is uniquely qualified to lead the next half century of military space system development. General "Bennie" Schriever's vision and legacy, begun here some 50 years ago, has produced unrivaled spacepower for the Nation. In the spring of 2006, SMC will move to brand new, state-of-the-art facilities at Los Angeles AFB, marking the "rebirth" of SMC. The next generation of space visionaries, innovators, and warriors will deliver world-class engineering, acquisition and operational capabilities to assure mission success.

We recently set a new military space record with the launch of the last Titan IV in October 2005—44 consecutive, successful major launches, breaking the previous record set in 1971. We have not lost the recipe! Mission success is key to providing on-orbit operational capability to an ever-growing community of warfighting users. Space development and acquisition will always be an extremely challenging and difficult business—it is, after all, rocket science! As our Nation and Allies grow more dependent on what we bring to the fight, the men and women of SMC understand they must continue to re-build the culture of excellence, be accountable, and take ownership of the mission responsibilities that have been entrusted to us. The "father of military space," General Schriever challenged us to "keep going, keep going" in his final days. Mission success will be our guiding principle and it will provide the very best future combat capabilities to achieve needed warfighting effects to deter aggression and win wars in the uncertain global environment of the 21st century.

Lt General Michael A. Hamel (BS, Aeronautical Engineering, US Air Force Academy, Colorado; MBA, California State University) is Commander, Space and Missile Systems Center, Air Force Space Command, Los Angeles Air Force Base, California. General Hamel is responsible for managing the research, design, development, acquisition and sustainment of space and missile systems, launch, command and control, and operational satellite systems. He is responsible for more than 6,500 employees nationwide and an annual total budget in excess of $10 billion. General Hamel is the Air Force Program Executive Officer for Space and is responsible for the Air Force Satellite Control Network; space launch and range programs; the Space-Based Infrared System Program; military satellite communication programs; the Global Positioning System; intercontinental ballistic missile programs; Defense Meteorological Satellite Program; the space superiority system programs, and other emerging transformational space programs.

General Hamel was commissioned as a second lieutenant through the US Air Force Academy in June 1972. His career includes assignments in a variety of command, acquisition, operations, and policy positions involving space, system development, intelligence, space operations, and launch. The general has served in senior staff positions at Headquarters US Air Force and Air Force Space Command, and he was the Vice President's military adviser on defense, nonproliferation and space policy. Prior to his current position, General Hamel commanded the 14th Air Force "Flying Tigers," and was responsible for all US Air Force space forces and operations as well as the execution of assigned US Strategic Command's space operations.

Successes and Challenges Facing the Acquisition System

Mr. Robert J. Stevens
Chairman, President and Chief Executive Officer, Lockheed Martin Corporation

When the warhead from an Iraqi Scud missile slammed into makeshift military barracks at Dhahran, Saudi Arabia, on the evening of 25 February 1991, the cost to US forces was steep. The powerful explosion and fire killed 28 soldiers and injured hundreds, marking the single deadliest incident involving Americans during Operation DESERT STORM.

That attack galvanized the US Department of Defense (DoD) leadership to find a better early-warning system. In 1995, DoD chose the Space-Based Infrared System-High (SBIRS-High) as the right system and Lockheed Martin as the right prime contractor.

Ten years later, as everyone in the space community is fully aware, the original timetable for SBIRS-High launches has not been achieved. What happened and why? And more importantly, what can be learned from SBIRS-High and other space modernization projects to ensure we do not encounter similar experiences that place our warfighters at a disadvantage? To answer those questions, we need to look closely at the business of space and the ways in which the government and industry interact.

The "Lost" Recipe?

Delays in the deployment of such systems as SBIRS-High, Future Imaging Architecture (FIA) and others, have caused some to suggest that our space community has lost its "magic recipe" for success and that "space is broken." While there is certainly ample room for improvement in our current practices, it seems to me that this criticism ignores some magnificent achievements, while vastly overstating the problems.

Those who think space is broken should be reminded that in October 2005, the US Air Force and Lockheed Martin closed out a proud five-decade history with the final launch of a Titan IV B rocket carrying a critical national security payload for the National Reconnaissance Office. It represented the 526th Titan built, the 368th Titan to fly and the 39th Titan IV mission.

Together, the government/industry team also recently achieved the 77th consecutive successful launch of our storied Atlas booster family. Further, deployed spacecraft are performing extremely well. Indeed, we are witnessing better performance and longer lifespan and seeing our systems being used in ways not originally envisioned to address threats in a flexible manner.

We recently completed a highly successful launch and on-orbit turnover of the first modernized Global Positioning Satellite (GPS), which will provide significantly improved navigation capabilities for both military and civilian users around the globe.

We would also point out to critics that space is completely different from other complex weapons systems and their procurement. The complexity of space systems and associated ground and launch systems are profound, so development challenges are inherent to our industry.

Clearly, operational space is not broken. Most of the challenges we face today have less to do with technology than with the process by which space programs are structured and procured.

Applying Lessons Learned

In 2003, the Defense Science Board (DSB) was asked to analyze why some space programs were encountering difficulty. Its findings zeroed-in on the acquisition process, pointing to:

- Cost as the most important selection criterion, incentivizing unrealistically low bids at the expense of mission success.
- Lack of discipline in the requirements process, leading to immature requirements baseline at program award and uncontrolled requirements growth thereafter.
- Insisting on modernizing every space mission area at the same time with a clear institutional bias for replacing incumbent providers.
- Atrophying systems engineering capabilities, undermining the government's ability to be a "smart buyer."
- Competition for the sake of competition.

Government and industry have been—and will continue to—work together to address these issues.

At Lockheed Martin, we have learned some valuable lessons. We have come to fully understand the importance of a strong, disciplined leadership team that can make tough decisions, enforce our high standards and effectively communicate with the customer. We have significantly strengthened the robustness of our systems engineering capabilities, now typically investing 11-15 percent up front to reduce risk. We have placed a greater focus on the laboratory environment, engineering units, and qualification units.

We have elevated our standards for Preliminary Design Review (PDR) and Critical Design Review (CDR) phases of programs and are employing an event-driven philosophy in which meeting the entrance and exit criteria for milestones takes priority over a date on the calendar. At Lockheed Martin, we have sharpened our external focus and are managing our subcontractors much more effectively. In addition, we have honed our management and engineering processes, adopting best practices to ensure success.

Lockheed Martin spending on internal research and development within our Space Systems Company has increased to over $100 million a year. We have also implemented creative programs designed to recruit and retain the best and the brightest to enhance our diverse workforce, ensuring access to critical human and intellectual capital.

From a customer standpoint, we believe the government has recognized the dire need for acquisition professionals with clear lines of authority and the responsibility and ability to deliver the best products possible to the warfighter.

Our customers understand the importance of the financial stability that allows the contractor to execute to the highest level. Having stability within the ranks of government leadership also is receiving the attention it requires. Both the industry and government fully recognize the value of a true partnership that can provide flexible and responsive solutions to program challenges.

As both government and industry apply these "lessons learned," we must be careful not to adopt practices that could exacerbate problems.

To illustrate, promises of "faster, cheaper, better" are always tempting, but for most of the important national security space mission areas, this approach is more likely to be "penny wise and pound foolish."

Additionally, although we are strongly supportive of efforts in the area of "operationally responsive space," we believe this approach is better viewed as a complement to existing systems rather than as an alternative. Small satellites can be powerful force multipliers in niche areas, but simply cannot replace enduring, mission-critical systems that are relied upon and utilized day in and day out when the warfighter or intelligence community calls.

We also would dispute the commonly held view that large aerospace companies are not agile and innovative. From the critical and innovative wartime satellite network we enabled in Iraq in just a few months, to our smaller satellite programs like the XSS-11—a 100 kilogram-class spacecraft designed to explore, demonstrate and flight-qualify microsatellite technologies—we have demonstrated that we can field highly innovative capabilities rapidly and at very low cost.

A Modest Proposal

We know complex space programs are always challenging. In order to maximize the probability of success, we believe the following methodology should generally be employed when considering a new program:

- Do not modernize for the sake of modernizing and do not compete for the sake of competition. If an existing system satisfies operational needs and the contractor is performing well, do not start a new program.
- If an existing system no longer meets requirements, first look for opportunities for evolutionary development as a way to expand capability and minimize cost and technical risk. The presumption should be an incumbent who is performing well is most likely to succeed in a timely and cost-effective way.
- Only start a new clean-slate space program if the incumbent is performing poorly or a fundamentally new capability is needed, either within an existing mission area where evolutionary development cannot produce the desired capability, or in an area where no program previously existed.
- Do not begin a new program until requirements have been validated, stable funding is in place, and adequate management reserves are available.

These ideas are not new or radical. It is how space programs were originally acquired. It is the reason many national security programs have been successful.

True Partnership Leads To Success

Historically, it has been true partnerships that have yielded extraordinary programs such as Milstar Block 2, the Defense Meteorological Satellite Program (DMSP), the Defense Satellite Communications System (DSCS), GPS, Titan, and Atlas that have served as the foundation for national security and military space.

It is our belief these types of partnerships are essential as we work together to set ourselves on a clear and defined path toward demonstrating to Congress and the American people we are able to effectively manage precious resources and taxpayer dollars.

We would point proudly to three Lockheed Martin franchise programs—Titan, Fleet Ballistic Missile, and U-2—which recently celebrated 50 years of customer support. These are perfect examples of government/industry teams working together in a true partnership to deliver needed mission-critical systems. These programs were not without their challenges over the years, both technical and financial, but the teams diligently worked together with high standards and integrity to deliver the needed mission capability. I am confident that space is on a similar course.

Robert J. Stevens (MS, Engineering and Management, Polytechnic University, New York; MBA, Business, Columbia University) serves as Chairman, President and Chief Executive Officer of Lockheed Martin. He has held a variety of increasingly responsible executive positions including Chief Operating Officer, Chief Financial Officer, and head of Strategic Planning through a career that has included experience in program management, finance, manufacturing, and operations.

Mr. Stevens is a Fellow of the American Astronautical Society and the American Institute of Aeronautics and Astronautics. He serves on the International Advisory Board of the British-American Business Council and on the Executive Committee of the Aerospace Industries Association. He is a member of the Council on Foreign Relations, is Presiding Director of the Monsanto Company, and a member of the Board of Directors of the Congressional Medal of Honor Foundation. During 2001 and 2002, Mr. Stevens served on President Bush's Commission to Examine the Future of the United States Aerospace Industry.

Mr. Stevens is a graduate of the Department of Defense Systems Management College Program Management course and also served in the United States Marine Corps. In 2004, he was recognized by the National Management Association as Executive of the Year.

The Three-Body Problem: Perspectives on Space Acquisition

Dr. Ronald D. Sugar,
Chairman, CEO, and President,
Northrop Grumman Corporation

Four years into the Global War on Terror, America's forces prove daily just how important space-based systems are to our national security. Every Global Positioning System (GPS) aided munition put squarely on its target; every satellite-relayed observation made by unmanned aerial vehicles; every enemy communication intercepted, underscores the importance of these systems. With this growing importance comes growing attention to the shortcomings of the processes by which these critical systems are acquired. The next generation of space systems currently in the acquisition pipeline is, in the aggregate, over cost, behind schedule, and of less capability than originally touted.

Anyone who understands the dependence of military transformation on these upcoming space-based systems needs to understand the issues attendant to their design, construction, and procurement. The many challenges in getting a system from concept to deployment come from different, but interrelated sources making the acquisition environment seem like a hopeless tangle. Though not hopeless, the issues are a tangle, so perhaps a metaphor would be useful.

The Three-Body Problem: Department of Defense, Congress, and Defense Industry.

The Three-Body Problem

Many Americans would say that a crowning achievement of man's quest for space remains our lunar landings, now over three decades old. There were many technologies that had to be invented from scratch to get us there, and one of them concerned the problem of navigation. Thanks to Kepler and Newton, mankind has understood the physics of relative orbital motion of two objects in space for hundreds of years. But the orbital motion of one body in the presence of two other bodies—themselves in motion—posed a mathematical problem that had defied solution since the days of Isaac Newton. In fact, as recently as the 1940s, mathematicians asserted this so-called Three-Body Problem was simply unsolvable. This is because each moving body exerted ever-changing gravitational effects on the others. Compounded over the vast distances of space, this problem posed a potential navigational hazard for any future space traveler.

Today, space acquisition faces its own Three-Body Problem. As in our metaphor, these three bodies are constantly in motion and constantly exchanging gravitational effects, which magnify dramatically over the course of the acquisition journey. Here the three bodies I refer to are the Department of Defense (DoD), the Congress, and the Defense Industry. Let's examine the most significant gravitational effects of each.

The Department of Defense

Let me begin with the DoD since it finds itself in the center of the forces at play. The Honorable Kenneth Krieg recently summed up his new role as Under Secretary of Defense for Acquisition, Technology and Logistics. He noted his responsibility to invest the taxpayer's money wisely in the capabilities necessary to defend our Nation and its interests, while helping the Secretary manage his department, and assisting Congress's oversight responsibilities.[1] At its heart lies the holy grail of every defense acquisition program: that the final capability, cost, and delivery date of a defense program comport within reason to the initial predictions.

A more difficult job could scarcely be imagined. For example, the demands of our national security—particularly in time of war—often require the reach of a program's design exceed the grasp of the current technology. This implies taking risk during the development phase which, in the past, was more readily tolerated. During the early days of the Cold War, our strategic missile and other rocket programs routinely suffered launch pad failures. The stakes of the Cold War, however, induced a national will to take risks, push the envelope, and fully commit significant resources in order to make us the greatest military force in the world.

One of the difficult challenges of today's acquisition environment is balancing performance requirements with risk. This is particularly true with space systems, which possess long development cycles and no forgiveness for failure once deployed. Unlike other weapons systems, on-orbit spacecraft cannot be "sent back to the shop" for repair. When the need for new capabilities results in a new program start, competition for that program can bring out the best ideas of industry to the benefit of the Nation. However, it is usually the case that the risks of a new program exceed those of simply improving the existing successful system to meet the new capabilities (so-called "Spiral Evolution").

The effect of human capital must also be considered in new program source selection. There is a difficult trade-off involving when to evolve a proven system (with the knowledge base of its experienced industry team) and when to call for a dramatic change in capability (which often results in an energized, if inexperienced, competitor).

Unrealistic cost estimates are another vexing challenge, one in which the government's gravitational pull affects industry. This is a fundamental structural dilemma in how new program starts are "sold" within the government, and how they are won by competing contractors. For various reasons, government (sometimes with the help of industry) typically underestimates a program's initial cost estimates, then budgets the program at the time of its birth at an amount even less than that. The message to industry is clear: cost matters, and a winning bid needs to be affordable, at least on paper. Corporations thus prepare their bid proposals with a degree of optimism commensurate with the government offices to whom they send them. The cost proposal often becomes a trap, preventing the contractor from including a prudent "risk management" reserve in its bid to cover the unexpected—but inevitable—challenges and costs of pushing that new technology. In the end, the final program costs are invariably higher than either the government's estimates or the contractor's proposed bid.

In recognition of this condition, the DoD elevated the Cost Analysis Improvement Group (CAIG) to a preeminent position as arbiter of DoD program cost estimates for all major DoD programs. In addition, DoD now budgets programs to the CAIG estimate. This was an important advance because the role of the CAIG is to serve as an independent "honest broker" among the various DoD estimating offices. As such, CAIG cost estimates on key programs have provided a more objective and accurate input for decision-making and it now leads the cost estimating of the various defense programs submitted for its analysis.

Northrop Grumman Corporation

Northrop Grumman Corporation

Micro electronic production laboratory.

At the end of the day, though, the most objective cost estimate is no better than the discipline of those who might allow the unchecked addition of new program requirements. This problem is particularly acute in space acquisition. The length of the development cycle, and the inability to change hardware once on orbit, leads to the desire to incorporate "leap-ahead" technologies. The need to accommodate the new demands of additional users unforeseen at the program's inception also contributes to the problem. The number and scope of Key Performance Parameters (KPP's) is often unwieldy even before the program is initiated. A 2003 Defense Science Board report on Space Acquisition found, "…requirements definition and subsequent control, or lack thereof, to be a dominant driver of cost increases, schedule delays and incurred mission risk," and it called for more disciplined leadership in the acceptance or rejection of additional requirements.[2] According to that board, the establishment of more than four or five KPP's for a satellite increases the risk of problems in development. At last count the Space Based Infrared System had 19. And while there are many factors that affect cost growth, requirements growth is prominent.

Finally, there is the human element to the DoD's role. Many senior managers in the acquisition chain of command often have limited experience in management of large systems. This is not surprising when one considers the average tenure for government program managers is less than two years. One reason is that, quite bluntly, this career track is not rewarded by the uniformed services or the civilian side of the DoD nearly as much as it should be. Developing skills, experience, and wisdom in program management is a long-cycle undertaking. There is far too little emphasis placed on the development and progress of program managers, with the result being inadequate skill levels and experience at the middle management level.

This is a serious problem. Far too many capable people leave the acquisition workforce due to such disincentives as uncompetitive pay, poor work environment, lack of appropriate authority, regulatory complexity, and personal career risk. Inadequate program funding and out-of-control requirements additions often leave aspiring government program managers with un-executable programs and impossible management challenges. We have many capable and dedicated government acquisition professionals, but we need to systematically address the human issues cited above to make a difference in the future.

Congress

The second of our three bodies is Congress, which exerts enormous gravitational force on the acquisition process for good reason: it writes the laws and appropriates all the money. Congress has a constitutional duty to the American people to ensure their money will be spent on the right things and be spent wisely.

In keeping with our Three-Body analogy, there is gravitational coupling between optimistic DoD cost estimates and Congressional behavior. Because these optimistic estimates (and sometimes ill-defined program requirements) eventually compound into cost overruns and schedule delays, Congress often rightly feels compelled to amend budgets midstream in a program's development. Well-intentioned attempts to cut or re-prioritize resources can render a good and needed program even further out of reach and further over budget. This, in turn, forces DoD program managers into wild scrambles to fix budgets, schedules, and capabilities, not just of the program in question, but of the other programs following in the queue. In orbital physics, this condition would be characterized as an unstable oscillation.

What makes Congress's job so difficult is that each member must serve the immediate interests of his constituents. Thus, the future of any long-term defense program is subject to the short-term forces of opinion of their respective electorates. Members must justify their continued support for programs that are often far over budget and behind schedule. However, for the good of our warfighters Congress must resist budgetary and funding actions that invariably cause major disruptions to a program's development down the line. In weapons systems, no current Congress wants to preclude options for, or obligate, a future Congress. However, for many major space programs past their initial development phase, multi-year contracts do offer a valuable mechanism for stable funding. Stably funded multi-year contracts have often been among the most successful space and weapons system programs.


Northrop Grumman Corporation

Detailed Congressional engagement in acquisition programs has increased over the past two decades, and for understandable reasons. This depth of engagement, while spurred by the problems that have occurred, has introduced a gravitational coupling of its own. Congress must demand realistic cost estimates, and provide oversight. It should exercise its constitutional responsibilities of authorization and appropriation in a way that supports and adds to the stability of the process.


Northrop Grumman Corporation

Assured command and control worldwide.

The Defense Industry

The last of our three bodies is the Defense Industry. The private sector defense industrial base is, of course, the essential partner to the DoD, providing our armed forces with the tools they need to defend our Nation. The Industry exerts enormous gravitational effects as well, because it is the principal source of the human capital, technological innovation, hardware, and software that comprise most of our space and other weapon systems. As pointed out by former Deputy Secretary of Defense, John Hamre, in his recent testimony to the Airland Subcommittee of the Senate Armed Services Committee, America made a crucial decision 80 years ago to buy most of its military aircraft (and later other advanced technologies such as missiles and spacecraft) from the private sector, not build them in government arsenals.[3] That decision, in contrast with the Soviet Union's reliance on state-run design bureaus, was principally responsible for the extraordinary qualitative advantage of our weapon systems over our Cold War adversary's numerical superiority. But as Dr. Hamre observes, today's defense industrial base is an increasingly smaller and fragile part of our economy. Where once in the mid-1980s there were nearly two dozen prime contractors, consolidation has left a mere handful today. The situation is even more acute for smaller sub-tier suppliers. More importantly, the combined market capitalization of all the corporations comprising the so-called "Military-Industrial Complex" (as President Eisenhower once characterized it), is now less than that of a single commercial software maker, Microsoft. And defense industry profit margins, even during the recent defense spending surge, fall short of most all other industrial sectors.

So why does any of this matter to the space acquisition dilemma? It matters because the basic motivation for defense companies, in addition to serving the security of our Nation, is to create value for the shareholders who have invested in them with their precious savings. And just as our Nation benefits from vigorous private sector competition in space and weapon systems acquisition, so too must defense companies compete for investment capital in the financial markets and for human capital in the high-technology workforce. Against a backdrop of fewer new program starts and increasingly ferocious competition, defense companies are compelled to win new business. Contractors therefore have an obligation to use all appropriate arrows in their bidding quiver. These include human capital, innovation, program experience, and capital investment in highly specialized laboratories, tools, and facilities. They may also include the enlistment of public support and members of Congress as program advocates. Failure to win new business can result in the loss of thousands of skilled workers, shareholder value, and perhaps even the continuing viability of the company itself.

Think now of the structural issues facing the DoD as it struggles to define the requirements/cost/risk equation for a potential new system. How can the Industry best engage to promote greater stability in the Three-Body Problem of acquisition? The Industry today is already highly responsive to the gravitational effects of the DoD and Congress. However, what is needed is not merely responsiveness, but greater *responsibility* as well. Contractors have a unique perspective on the interplay of performance, cost, and risk. They are also subject to intense competitive pressures. Despite these pressures, contractors have an obligation to provide government with greater *candor* in competitive bids. In so doing, this will improve the realism of DoD budgeting and source selection processes. This candor must start during the earliest stages of program formulation before the final Request for Proposal is issued. And once under contract, Industry must *perform* more responsibly on the promises made. In a nutshell, "Do what you say you will do."

Human capital comes into play here as well. The graying of our space and defense industry workforce has resulted in an enormous collective loss of capabilities and experience. For space and missile work, we must never forget how special the work is. This really still is "rocket science."

Industry must more aggressively recruit, train, and motivate a new generation of talent across all skill sets. Without a doubt, the highest leverage on improving contractor performance will come from strengthening the skills of systems engineering and program management.

Final Thoughts

So, here is our own Three-Body Problem in which each body—the DoD, Congress, and Defense Industry—exert gravitational pulls on the other two: DoD acquisition practices sometimes create adverse incentives for Industry, which are in turn compounded by those in Congress whose help is often needed to win or preserve a contract. Optimistic government cost estimates result in appropriated funds, which are inadequate to cover the inevitable risks of advanced technology, causing hard-pressed program managers to constantly re-plan and re-prioritize. The ripples produced become shock waves of disruption. Industry must respond to its own growth and survival imperatives and submit bids that may be unworkable. Programs fall behind, exceed budget, and fail to meet original performance objectives. And so it goes. Each body affects the trajectories of the others. It is too easy for these forces, if not checked, to produce unstable oscillation causing our three critically interdependent bodies to fly apart.

How do we work our way out of this tangle? There are no simple answers, but several thoughts do come to mind: For DoD, a greater emphasis on disciplined requirements management, and investment in the human capital of its professional acquisition corps; for the Congress, a longer view, constancy of support, and a move to macro-oversight contributing to stability; and for the Defense Industry, greater candor in its interactions with government, and a renewed focus on performance. Each of these suggestions will go a long way as we sort out the complex details of acquisition reform.

Despite the enormous difficulties we face in space and weapon acquisition, we must remember the acquisition system we have today has produced the most potent warfighting capability ever fielded. Not all is broken, not all is bad. The need to improve the acquisition system is, however, imperative and it must be a matter of collective will. The stakes for our Nation are too high not to succeed.

Dr. Ronald D. Sugar (BS, MS, and PhD, University of California at Los Angeles) is chairman of the board, chief executive officer and president of Northrop Grumman Corporation, one of the world's top defense companies. He began his career at The Aerospace Corporation in research and development of space and missile systems, and later held technical and executive positions at Hughes Aircraft Company, TRW Inc. and Litton Industries. During his more than 35 years of professional experience he has participated in the acquisition of a broad range of defense systems including combat aircraft, naval ships, defense electronics, command and control systems, communications, and software systems. Dr. Sugar currently serves as chairman of the Aerospace Industries Association, trustee of the Association of the United States Army, trustee of the University of Southern California, and is a member of the board of directors of Chevron Corporation. He is a member of the National Academy of Engineering, a fellow of the American Institute of Aeronautics and Astronautics, and a fellow of the Royal Aeronautical Society. He earlier was appointed by the President of the United States to the National Security Telecommunications Advisory Committee. Dr. Sugar completed executive studies at Harvard, Stanford and Wharton.

Notes:

[1] The Honorable Kenneth Krieg, Under Secretary of Defense of Acquisition, Technology, and Logistics (speech to National Defense Industrial Association, 21 September 2005).

[2] Defense Science Board/Air Force Scientific Advisory Board, Joint Task Force, "Acquisition of National Security Space Programs," May 2003, 27, sec. 6.3., http://www.acq.osd.mil/dsb/reports/space.pdf

[3] John Hamre, former Deputy Secretary of Defense, "CSIS President Dr. John Hamre's Capitol Hill Testimony addresses Defense Procurement Policy," (testimony to the Airland Subcommittee of the Senate Armed Services Committee, 15 November 2005)

Overcoming Space Acquisition Problems

Mr. Robert E. Levin
Director, Acquisition and Sourcing Management
US Government Accountability Office

For the modern warfighter, space systems are becoming increasingly critical to every facet of military operations, but also more costly. These systems allow us to, among other things, collect information on the capabilities and intentions of potential adversaries, be warned of missile attacks, and communicate and navigate while avoiding hostile actions. In fiscal year (FY) 2006, the Department of Defense (DoD) expects to spend about $20 billion to develop and procure unclassified satellites and other space systems, including some $7 billion on the major space systems, and these amounts are expected to increase. In fact, DoD spending to develop and procure the major unclassified systems would double by 2011 under the FY 2006 President's budget request.[1]

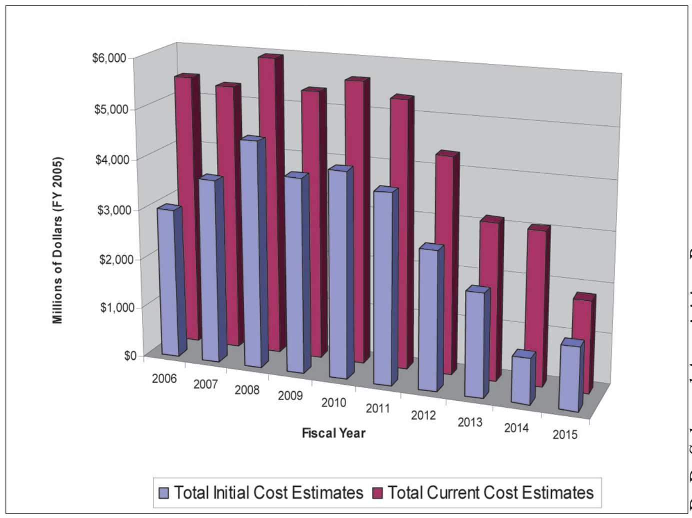
Over the past several years, the US Government Accountability Office (GAO) has evaluated space system acquisitions on behalf of Congress to determine their status at different points in time, drilling down into the details of the programs. We have also analyzed space system acquisitions more broadly to identify common and causal factors for poor outcomes. These factors need to be clearly understood in order to develop solutions to these acquisition problems. In this article, I will present some of our major findings regarding these common factors as well as GAO's recommendations for overcoming space acquisition problems.

Problems Affecting Space System Acquisitions Persist

For decades, space acquisition programs have been incurring large cost increases and schedule delays. As a result, DoD has been unable to deliver capabilities as promised and the Department has lost credibility with Congress. This past year, for example, costs continued to climb on the Space Based Infrared System High (SBIRS-High) program, triggering its third Nunn-McCurdy review and pushing DoD's investment in this critical missile warning system to more than $10 billion, from the initial $3.9 billion estimate made nine years ago.[2] At the same time, programs focused on developing new communications satellites are facing cost increases and schedule delays, the National Polar-orbiting Operational Environmental Satellite System has been restructured and is facing cost increases and schedule delays, and unit cost increases for launch vehicles have now increased by 81 percent since 2002.

Taken together, these problems have had a dramatic impact on DoD's overall space portfolio. For example, DoD has had to shift scarce resources to poorly performing programs, and cost increases have kept DoD from investing more in science and technology efforts that support space. At the same time, DoD is attempting to undertake new efforts—including Transformational Satellite Communications System (TSAT) and Space Radar—which are expected to be among the most expensive and complex space systems ever produced.

As figure 1 illustrates, there is a vast difference between DoD's budgeting plans and the reality of the cost of its space systems. Over the next 10 years, given past trends, space systems, on average, will cost DoD in excess of $1.5 billion more annually than it had originally planned. This means there is $1.5 billion less that DoD has to spend on other priorities annually and tens of billions less available for DoD's overall weapons portfolio over time.



DoD, Selected Acquisition Reports

Figure 1. Comparison between original cost estimates and current cost estimates for major space systems acquisitions underway.

Accommodating these additional costs should prove a significant challenge for DoD's budget given the current fiscal environment. First, DoD acquisition programs for space and other systems are considered "discretionary spending" in the federal budget. As "mandatory spending" on programs such as Social Security and Medicare increases, DoD programs will likely be competing with other discretionary programs, such as relief for Hurricane Katrina victims, for a decreasing share of the federal budget. Second, within DoD, space systems must compete for funding against growing military personnel costs, especially health care, spending on the war in Iraq, cost growth of all defense weapon systems, new non-space program starts, and other requirements.

Why Does DoD Continue to Experience Space Acquisition Problems?

We have analyzed the range of space acquisitions over the last several years to identify the common and causal factors for these poor acquisition outcomes. Specifically, we identified the following two factors as primary drivers.

...requirements were not adequately defined at the beginning of a program or were changed significantly once the program had begun, technologies were not mature enough to be included in product development, and/or cost estimates were unreliable.

1. **DoD seldom matches resources to requirements at the start of an acquisition program**

   Space programs have typically not achieved a match between requirements and resources (available technology, time, and money) at program start. In other words, the programs did not have the level of knowledge needed to assure they could be completed within expected cost and schedule estimates. For example, requirements were not adequately defined at the beginning of a program or were changed significantly once the program had begun, technologies were not mature enough to be included in product development, and/or cost estimates were unreliable.

   There are a number of cross-cutting factors that help explain why DoD has trouble matching resources to requirements:

   - The broad constituencies generally behind satellite programs – contractors, military services, intelligence agencies, Congress, and others – create increased requirements pressures not otherwise found with other weapon systems. The Global Positioning System (GPS), for example, not only serves military users, but also serves civilians, supports various economic sectors, and is used by allies. This creates challenges in making tough tradeoff decisions.
   - Space acquisition programs have historically attempted to satisfy all requirements in a single step, regardless of the design challenge or the maturity of the technologies. There are a variety of reasons for this, including a desire to include the most advanced technologies onboard satellites. However, this approach invariably increases the technology challenges facing the programs.
   - There is a tendency to take on technology development within the acquisition program rather than in the science and technology (S&T) environment. This happens largely because there is a greater ability to secure funding for costly technology development within an acquisition program than in an S&T program, and because there are communication gaps between the S&T and acquisition communities. Nevertheless, allowing technology development to carry over into product development increases the risk significant problems will be discovered late in development. Moreover, when there are many unknowns about critical technologies, a program cannot reliably estimate how much it will truly cost or how long it will actually take for capabilities to be delivered.

2. **DoD funds programs continually without consistently establishing priorities**

   DoD's space programs, along with other federal programs, are on a continuous funding cycle. DoD as a whole rarely establishes stable, consistent funding priorities to help guide decisions made during these cycles. This sets the stage for a constant state of competition between all DoD programs, which results in program officials and contractors underestimating costs and over-promising capability in order to be competitive and secure funding. This also creates a host of negative incentives and pressures, which include the following:

   - Because they continuously compete for funding, programs view success as securing the next installment rather than delivering capabilities.
   - Having to continually "sell" a program creates incentives to suppress bad news about a program's status and to avoid expensive technology testing in space before acquisition programs are started.
   - When faced with lower budgets, senior executives find it easier to make across-the-board cuts instead of hard decisions as to which programs to keep and which to cancel or cut back.

   These pressures are long-standing and common to weapon acquisitions, not just space acquisitions. The competition within DoD to win funding and get approval to start a new program is intense and creates strong incentives to make a weapon system stand out from existing or alternative systems. In the process of doing this, competing contractors typically submit proposals that reflect minimum program content and a "price to win."[3] Thus, ultimately, DoD ends up starting more programs than it can afford in the long run because it bases its decisions on unrealistically low cost estimates. Figure 2 further highlights the cycle of pressures that forms when DoD initiates too many programs with too little funding.

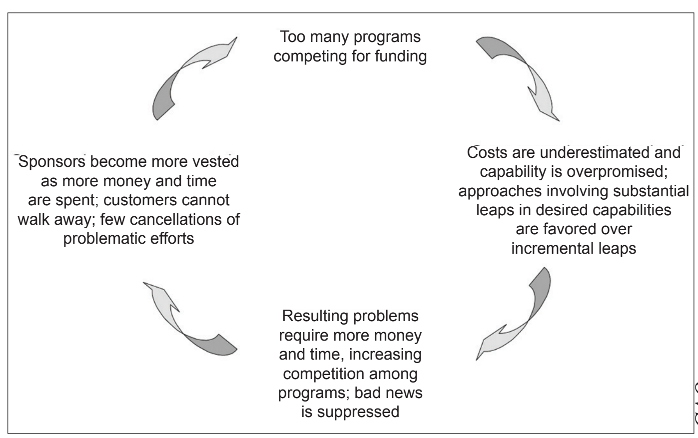


Figure 2. Overview of pressures resulting from beginning more programs than DoD can afford in the long run.

Overcoming Space Acquisition Problems Will Require Stronger Development Practices and Investment Planning

Our work has shown fundamental changes are necessary to stem cost and schedule increases and enable DoD to field new capabilities more efficiently and effectively. DoD must find ways to match resources to requirements before it starts new programs and to have an investment strategy in place to guide difficult annual funding decisions.

To address past problems, DoD has begun by establishing the Joint Capabilities Integration and Development System (JCIDS), revising its National Security Space Acquisition Policy (03-01) to increase its knowledge before committing to a program start, developing a space science and technology strategy, and strengthening its systems engineering capabilities. However, we feel more is needed, and that the following actions, in particular, would help DoD better match resources to requirements.

Implement processes and policies that stabilize requirements. Our reports over the years, as well as many DoD studies, have pointed to a need to stabilize requirements for all weapon system development. Along these lines, the Air Force has instituted high-level boards for key systems such as SBIRS-High and Space Radar to approve new requirements and processes thereby ensuring the right officials are involved. However, when we reported on Space Radar in 2004, even these changes were not ensuring the intelligence community – a major stakeholder – was in agreement with requirements and that all stakeholders would be held accountable for their agreements. DoD is now working on strengthening its partnership within the Space Radar program to avoid this problem.

Another key to success is employing systems engineering to close the gaps between available technologies and customer needs before committing to new product development.

Create an overall investment strategy. Our recent reports on space and other weapon systems have suggested having a department-wide investment strategy for weapon systems would help reduce pressures facing acquisition programs. Critical components of such a strategy would include identifying overall capabilities and how to achieve them, that is, what role space will play versus other land-, sea-, and air-based assets; identifying priorities for funding; and implementing mechanisms that would enforce the strategy. For space in particular, a strategy would help DoD rebalance its investments in acquisition programs as it continues to contend with cost increases from its programs. Moreover, it would also help with balancing investments between S&T and acquisitions.

Separate technology from acquisition. DoD's practice of taking on technology development concurrently with product development stands in sharp contrast to those practices followed by successful programs and the approach recommended by DoD's acquisition policy for weapon systems. Successful programs will not commit to undertaking product development unless they have a high confidence they have achieved a match between what the customer wants and what the program can deliver. Technologies that are not mature continue to be developed in an environment focused solely on technology development. Another key to success is employing systems engineering to close the gaps between available technologies and customer needs before committing to new product development. This puts programs in a better position to succeed because they can focus on design, system integration, and manufacturing.

As mentioned above, DoD has made some efforts to address this problem, including revising its space acquisition policy and developing a space S&T strategy. However, GAO remains concerned these measures will not be sufficient. The space acquisition policy, for example, still allows programs to begin before demonstrating technologies in an operational or simulated environment.

Adopt an evolutionary development approach. Evolutionary development means pursuing incremental increases in capability versus significant leaps. Our examinations of best practices have found this approach can decrease time and cost for development because it closes gaps in unknowns. The space acquisition policy states its preference for evolutionary development, and DoD has pursued evolutionary approaches in the past with GPS. But, more often, it has attempted to achieve significant leaps in capability in one step. Moreover, beginning programs by challenging program managers to achieve significant leaps in capability with the intention of abandoning those efforts later in the development cycle should too many problems be encountered is not a true evolutionary approach.

Address other resource shortfalls. Our reports have identified other resource gaps that should be addressed by DoD. These include shortages of staff with science and engineering backgrounds, deficiencies in the program manager workforce, decreased funding for testing space technologies, and increased costs to launch experiments. On behalf of Congress, GAO is currently reviewing DoD's efforts to revitalize its space workforce and to develop more realistic cost estimates.

In conclusion, there is no question space acquisition programs are encountering cost increases and schedule delays that are having negative effects on DoD's ability to deliver current and future capabilities and the Department's ability to maintain credibility with Congress. Many of these problems are rooted in past mistakes and their impact will be felt for years to come. Nevertheless, it is exceedingly important that DoD takes whatever midcourse corrections it can and ensures it has a foundation in place that puts acquisition programs on a better path, particularly since DoD is counting on its future space programs to play an increasingly critical role in national security and military operations.

DoD has taken some steps in the right direction. Yet the Department must still adopt practices that better match resources to requirements before starting its acquisition programs and decide exactly what role space will play in achieving future desired capabilities and what programs merit the highest priorities. At the same time, DoD must continue its efforts to assure it has the right resources to carry out technically challenging programs and it must continue to seek ways to deliver capability much more efficiently and effectively. All of these changes will not be easy to undertake. They require significant shifts in thinking about how space systems should be developed, changes in incentives and perceptions, and further policy and process changes.

Notes:

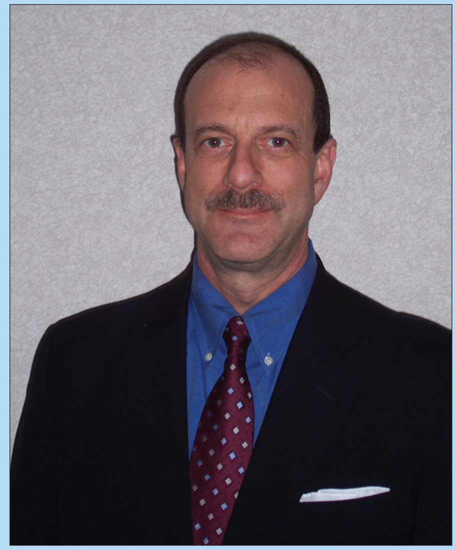
[1] Congressional Budget Office, *The Long-Term Implications of Current Plans for Investment in Major Unclassified Military Space Programs,* September 2005.

[2] Under this unit cost reporting mechanism, program unit cost increases – known as Nunn-McCurdy "breaches" – of 15 percent or more trigger a requirement for detailed reporting to Congress about the program, while increases of 25 percent or more also trigger the requirement for Secretary of Defense certification.

[3] Defense Science Board and Air Force Scientific Advisory Board, *Report of the Defense Science Board/Air Force Scientific Advisory Board Joint Task Force on Acquisition of National Security Space Programs,* May 2003.

Author's Note:

The Government Accountability Office (GAO) is an independent and non-partisan agency that works for Congress to study programs and expenditures of the federal government. Unless otherwise noted, information in this article is based on two GAO products: *Space Acquisitions: Stronger Development Practices and Investment Planning Needed to Address Continuing Problems* (GAO-05-891T, July 2005); and *Defense Acquisitions: Incentives and Pressures That Drive Problems Affecting Satellite and Related Acquisitions* (GAO-05-570R, June 2005). They can be found at www.gao.gov. This article was prepared with the assistance of Leslie K. Pollock, Defense Analyst, GAO.



Robert E. Levin (BA, Government, University of Virginia; MPA, Public Administration, Ohio State University) joined the Government Accountability Office in 1974 and has been a director in Acquisition and Sourcing Management since October 2000. His areas of responsibility include acquisition programs supporting the defense missions of intelligence, surveillance, reconnaissance, missile defense, communications, and command and control.

Before working on defense acquisitions, Mr. Levin worked for more than 25 years on such issues as transportation, agriculture, and intergovernmental relations. As an assistant director in the transportation area, he reported on air traffic control system modernization, airport development, aviation safety, and FAA organization, culture, and finance.

Mr. Levin also attended Harvard University as a senior executive fellow.

Today's National Security Space Acquisition Environment: Learning From the Past – A Path Forward

Maj General John T. "Tom" Sheridan
Program Executive Officer and System Program Director, Space Radar, Chantilly, Virginia

The United States has become increasingly reliant on space systems for communications, signals and imagery intelligence, early warning, tracking, navigation, and weather forecasting. For more than forty years, the Air Force and National Reconnaissance Office have been developing and acquiring leading edge technologies and space systems to support the ever-evolving needs of our Nation. This increased reliance on space for national, military, and civil applications is driving increased emphasis on timely development and fielding of national security space systems.

The new emphasis on transformational space systems is exemplified by the development of Space Radar (SR) and the Transformational Satellite Communications System (TSAT). With recent developmental difficulties confronting a number of large space systems, the national security space acquisition system faces greatly increased scrutiny by all stakeholders and must deliver capable systems in a highly constrained budget environment. Recent congressional reports have cited that research, development, test and evaluation (RDT&E) costs for Department of Defense (DoD) space systems have grown an average of 69 percent from original development estimates, and procurement costs on average have risen 19 percent in the same period. In addition, these programs have experienced schedule slips to varying degrees with system performance in some cases falling short of that which was originally planned.[1]

In developing SR, we plan to take advantage of achievable and buildable advances in technology, relying on rigorous and robust approaches in system integration and engineering, while at the same time, building close partnerships between the Integrated Program Office (IPO), the contractors, and the user communities. Utilizing Electronically Scanned Array (ESA) technology, SR will provide operationally significant capabilities in synthetic aperture radar (SAR), surface moving target indications (SMTI), high resolution terrain information (HRTI), advanced geospatial intelligence (AGI), and open ocean surveillance (OOS) to DoD and Intelligence Community users. Additionally, some products could be made available to civil users to support disaster relief and crisis response. SR will be built "inter-dependently," which means it will be integrated from a tasking, processing, and dissemination sense with other intelligence, surveillance and reconnaissance (ISR) systems towards the goal of persistent surveillance and reconnaissance, that is, knowing something about everything in a time responsive fashion.

US Air Force

Col Clarence L. "Lee" Battle

As SR works to get "off the ground" as a new program, the IPO is facing tough scrutiny of its risk reduction and acquisition strategies, its cost estimates, its understanding of still-developing requirements and its ability to assemble the right team to successfully accomplish this highly complex mission. A pertinent question is: What can we learn from our past, to better understand our present situation, and to properly prepare for the future? One space pioneer stands out, a man whose work I believe significantly helps attain such an understanding, Col Clarence L. "Lee" Battle. Colonel Battle was assigned to the Air Force Western Development Division in 1954. In 1958, he was appointed Program Director of the Discoverer/Corona program, our Nation's first space reconnaissance program. His mission was to develop, build, field, and operate the first space-based photo-reconnaissance system with access to any and all areas of the world. Timelines were tight. The first launch attempt occurred on 28 February 1959. The first 13 missions failed for one reason or another; but in August 1960, Discoverer XIV operated as planned. Its film bucket was safely returned on 19 August, containing 3,000 feet of film providing images with a ground resolved distance of 30-40 feet, of territory behind the "Iron Curtain." The program became an astounding success. Colonel Battle developed ten "Principles" for how to run a successful acquisition program. I have carried a copy of them with me since I first learned of them in 1982.

Here are Col Lee Battle's Ten Principles, in his order of importance:

1. Keep the Program Office small and quick-reacting at all costs.
2. Exercise extreme care in selecting people, and then rely heavily on their personal abilities.
3. Make the greatest use possible of supporting organiza-

tions. Sometimes you will have to make unreasonable demands on them to help you. Do it.
4. Cut out all unnecessary paperwork.
5. Control (guide) the contractors by personal contact. Each program office person will have a specific set of contractor contacts with whom he is responsible for constantly communicating.
6. Hit all flight and checkout failures hard. Any developmental fault not fixed early will come back to haunt you.
7. Rely strongly on contractor technical recommendations. (I would add: Rely strongly on Federally Funded Research and Development Center's recommendations as they help evaluate contractor performance and decision making).
8. Don't over-communicate with higher headquarters (This isn't really practical today with instantaneous communications).
9. Don't make a federal case about budget shortfalls. These matters usually fix themselves.
10. Don't look back, history never repeats itself.

I don't think we will ever face an environment exactly like the one Colonel Battle and his team worked in. However, the comparison between their situation and ours provides food for thought. They were a major knowledge provider near the start

I believe many of Colonel Battle's principles are still very valid for success in today's environment where the enemy is unknown and resources are increasingly scarce.

of the Cold War, and today, we require persistent knowledge of an ever-changing world environment, while faced with numerous dangers to our national security. I believe many of Colonel Battle's principles are still very valid for success in today's environment where the enemy is unknown and resources are increasingly scarce. For instance, very close, regular communications and insight between the contractor and the program office, learning about and fixing problems at the earliest possible time in program development and relying on a small team of very capable people and trusting their judgment, are all still very valid today. To these I would add the need for stable, "buildable" program requirements, strong regular user interface, predictable, stable funding that is matched to the scope of work required on the program, and a reasonable management reserve (MR). Additionally, the MR must only be employed to fix emerging program problems, not to support new requirements. I would suggest if we all keep these elements in mind and strive to collectively implement them as a team as we conduct space system acquisition, our record for on-schedule, at-planned-cost development, that meets user needs, will dramatically increase. Thanks Colonel Battle, for some great advice. Now it's our turn to implement!

Maj General John T. "Tom" Sheridan (BS, Mechanical Engineering, University of Connecticut; MBA, Bryant College, Rhode Island) is Program Executive Officer and System Program Director for Space Radar, Chantilly, Virginia. He directs a program designed to satisfy both Department of Defense and intelligence community needs as part of a system of systems integrated approach toward persistent surveillance and reconnaissance capability for the Nation.

General Sheridan's experience includes acquisition leadership of aircraft, simulator and classified space programs; requirements development across all Air Force space programs; and operational leadership in four different national space programs. He has served as military assistant to the Assistant Secretary of the Air Force for Space, and as the Commandant of Air Command and Staff College, Maxwell Air Force Base, Alabama. Prior to assuming his current position, the general was the Director of Requirements at Headquarters Air Force Space Command in Colorado Springs, Colorado.

Space Acquisition Today

Mr. Richard W. McKinney
Director, Space Acquisition
Office of the Under Secretary of the Air Force

The success of the United States national security space programs depends on effective acquisition, management, execution, and oversight. The United States' Department of Defense (DoD) is the world leader in acquiring military space systems, but continues to face challenges. The purpose of this article is to describe the strategic context in which space systems are acquired, identify the key organizational relationships among stakeholders, and describe one of the major challenges for space acquisition.

In the past decade, there has been a fundamental shift in how we acquire space systems. Various commissions and studies identified numerous problems that previously plagued space acquisition and as a result, the DoD directed significant changes to the management and organization of military space. Because the Air Force manages the majority of military space resources, the Air Force was and still is the primary focus of these changes. Among the several external and objective reviews, the most impacting was the Space Commission.

In 2000, Congress recognized the United States' growing dependence on space systems and the potential vulnerability of National Security Space systems. The Commission to Assess United States National Security Space Management and Organization ("The Space Commission") was established to review and recommend changes to national security space management and organization that would strengthen national security. The Commission's specific charter included assessing interagency coordination, the relationship between the intelligence and non-intelligence aspects, professional military education institutions, and the potential costs and benefits of establishing other management structures.

In 2001, the Space Commission completed its report and recommended that the President establish space as a national priority. In addition, a number of recommendations involved realigning Air Force Headquarters and field commands to more effectively organize, train, and equip for space operations. The Space Commission recommended the Secretary of Defense (SecDef) designate the Air Force as the DoD Executive Agent for Space, align Air Force and National Reconnaissance Organization (NRO) space programs, establish a Major Force Program for Space, and designate the Under Secretary of the Air Force (USecAF) as the Air Force Acquisition Executive for Space.

In response to the Space Commission recommendations, the DoD developed a comprehensive approach to national security space management and organization that resulted in merging disparate space activities, adjusting chains of command and establishing avenues for interagency relationships. The Air Force became the single manager for DoD space acquisition with the USecAF as the key decision-maker for all space programs. In addition to serving as the Deputy to the Secretary of the Air Force and Component Acquisition Executive (CAE) for Air Force Space programs, the USecAF became the Milestone Decision Authority (MDA) and the DoD executive agent for all DoD space systems—including Army and Navy.

Other changes resulting from the Space Commission included organizational realignments to more closely integrate acquisition and operations. The Space and Missile Systems Center commander is dual-hatted as the Program Executive Officer (PEO) for Space and reports directly to the USecAF to provide program execution oversight. The responsibility for execution of DoD space systems flows from the MDA through the CAE to the appropriate PEO and system program director or program manager.

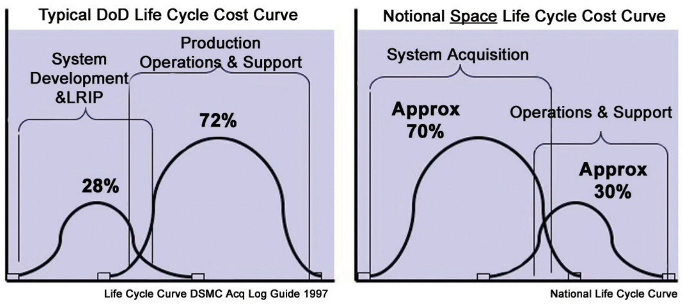
Another subtle but impacting change from the Space Commission was establishing a virtual major force program (vMFP) to better manage fiscal resources for space. A major force program (MFP) is a funding category used within the DoD and Congress to track and manage fiscal investment. The vMFP for space provides increased visibility to ensure space is adequately resourced. These changes, motivated by the Space Commission, fundamentally altered how the DoD acquires space systems and drove an organization restructure at headquarters USAF.

Prior to the Space Commission, a directorate within the Assistant Secretary of the Air Force for Acquisition performed the headquarters function of executing acquisition policy and budget for space programs. In 2001, the SecDef directed the Secretary of the Air Force (SECAF) realign appropriate staff functions within the Air Force Secretariat to the USecAF.

In April 2002, the Office of the Under Secretary (SAF/US) was established by consolidating and realigning responsibilities. The offices headed by the Assistant Secretary of the Air Force; the Deputy Assistant Secretary; the Air Force/NRO Integration Planning Group; the Director, Space and Nuclear Deterrence; Assistant Secretary of the Air Force, Space; and Space Plans and Policy were replaced by the Director, National Security Space Integration (SAF/USI) and Director of Space Acquisition (SAF/USA). SAF/USI is also known as the National Security Space Office (NSSO). The NSSO encompasses the National Security Space Architect, which develops middle and long-term architectures and works to integrate activities of all National Security Space organizations, including the NRO.

As part of the Office of the Under Secretary, SAF/USA plays an important role in space acquisition. SAF/USA is responsible for acquisition strategy, management policy, defense budgeting and decisions for our space programs. In addition to supporting activities within the DoD, SAF/USA maintains close contact with Congress, advocating for and providing insight to Air Force space programs.

Key to the Air Force reorganization was the authority of the MDA to create a new streamlined acquisition policy for space systems. This was motivated in part by the need to align Air Force and NRO acquisition "best practices" and the fact that ac-



quiring space programs significantly differs from other terrestrial acquisition programs.

The fundamental difference in space programs is they incur a larger percentage of their life cycle costs before deployment than non-space programs. The above figure shows a notional life cycle comparison of DoD systems and space systems. Although space systems are composed of ground-based control systems and terminals, the space-based portion of the system drives key decisions as the impact of failure is greatly magnified. Systems must work when placed on-orbit for long periods of time, without maintenance, in some cases 10 years or longer. As a result, getting the systems engineering right before launch is crucial to program success. Additionally, small production runs mean getting it right the first time. There are rarely "test" or "prototype" satellites. The acquisition process and policy needed adesign with these factors in mind.

In 2002, SAF/USA, working closely with the NRO, set out to define an acquisitionpolicy tailored to the unique aspects of space systems. The resulting policy is the National Security Space (NSS) Acquisition Policy 03-01. While under the general processes of the DoD Directive for acquisition, DoD 5000.1, NSS Acquisition Policy 03-01 provides specific acquisition guidelines for DoD space efforts. It emphasizes use of key decision points earlier in the space programs' life cycle than the DoD equivalent (DoD Instruction 5000.2), to coincide with greater acquisition costs and technology advances. NSS Acquisition Policy 03-01 requires independent program assessments and independent cost estimates at each key decision point. Over a four- to six-week period, these teams conduct a full-time peer review of all facets of the program relevant to its development stage. The results of the independent reviews are presented to the USecAF. The USecAF chairs a defense space acquisition board with members of the national security space community to solicit advice for his final decisions and approval to move into the next acquisition phase.

While NSS Acquisition Policy 03-01 sets the foundation in place for how space programs are acquired, it is only a foundation. Additional guidelines are needed in order to address current acquisition issues. In the past there was an unequal emphasis placed on cost, schedule and performance. The focus on performance often drove delays in delivery of the system. A balanced approach is needed so systems are delivered on time with known cost and performance.

The current USecAF, Dr. Ronald M. Sega, has outlined a balanced approach to space acquisition. Think of four levels of space systems: operational, developmental, experimental, and science and technology. While all are related, the purpose of each is separate and distinct. Operational systems should consist of technologies that are proven and well in hand. Generally, development should not be done concurrently with operational systems. The developmental level focuses on proving technology for insertion into operational systems. The experimental level embraces emerging technologies at increased risk with such high pay-off that some systems may not work. It is better when this occurs on the experimental level rather than in an operational system. The science and technology level provides the base for all future capabilities. Using this construct of four levels will allow systems to become operational at a lower overall risk, with much better ability to deliver capabilities on time, on cost and with known performance.

One of the most important facets of space acquisition is program management, which requires a renewed focus. The vast majority of space acquisition issues would be greatly minimized if government and industry applied sound management practices. The ability to manage programs requires practiced knowledge in both program management and system engineering. In other words, experienced managers should lead the major space programs. All too often the focus is on the technical aspects of the program – as appropriate. But if government and industry can't apply a sound management approach to these programs, the programs will not succeed.

In summary, the new organizational structure, the ability to separate developmental from operational systems and a renewed focus on program management are key to achieving success in space acquisition.

Richard W. McKinney (BS, Business Administration, Washington State University; MBA, University of Montana; BS, Electrical Engineering, AFIT) a member of the Senior Executive Service, is Director, Space Acquisition, Office of the Under Secretary of the Air Force, Washington, D.C. He directs development and purchasing on space and missile programs to Air Force major commands, product centers and laboratories dealing with acquisition programs. His responsibilities include crafting program strategies and options for representing Air Force positions to Headquarters, US Air Force, the Office of the Secretary of Defense, Congress, and the White House.

Mr. McKinney is a 1973 distinguished graduate of the Air Force ROTC program. He is certified level three in the acquisition areas of program management, acquisition logistics, and systems planning, research, development, and engineering. Prior to assuming his current position, McKinney was a private consultant. He retired from the Air Force in the rank of colonel in May 2001 after 28 years active duty. He was appointed to the Senior Executive Service in January 2002.

"A Crisis Situation": Danger and the Crucial Point

Brig General Katherine Roberts
Principal Director to the Deputy Assistant Secretary of Defense for Forces Policy

"…military buying has reached 'a crisis situation'."[1] Just the latest comment in a multi-decade litany of concerns, frustrations, and barbs dealing with Department of Defense (DoD) acquisition. The questions on the minds of our senior leaders are the same ones that have been asked for years. Why can't we seem to fix acquisition? Why does it take so long to field stuff? How do we get the stuff we need, when we need it, with the money we have? Between 1975 and 2001 there were 128 attempts to answer those questions.[2] Once more we have several efforts either underway or getting ready to start that are looking at how to fix acquisition. The first of these efforts to report out is expected to be the Defense Acquisition Performance Assessment (DAPA) project commissioned by acting Deputy Secretary of Defense Gordon England.[3]

The space portion of the almost $500 billion DoD budget in fiscal year 2004 was approximately four percent, nearly $21 billion.[4] This is a significant amount in a time of increasing budget pressure along with mother nature driven shifts in national priorities.[5] Although much has been done in recent years to turn space acquisition around, we are not there yet. General Lance W. Lord, in his Commander's Statement carried in the previous edition of *High Frontier,* listed his top three priorities for Air Force Space Command.[6] He then pointed out that successful accomplishment of those priorities could only occur if there was a solid foundation upon which to build. He described the foundation as composed of three common prerequisites for success that cut across each of the priorities. "First, we have the urgent need to develop our space professionals and prepare them for success…Our second prerequisite is space acquisition…Third, we must continue to demand nothing short of excellence in space and missile operations."[7] This article focuses on General Lord's number two prerequisite – space acquisition. My intent, at this crucial point, is to describe the dangers that exist, to identify the questions that need to be discussed, which are likely to be outside the scope of the current acquisition reform studies, and highlight areas within our control as space acquisition professionals where we can do better.

The National Security Environment

Any discussion of DoD space acquisition must be done in the context of our National Security. In my opinion, the current national security environment is defined by the word "transition." We are in a time of transition from the Cold War to something else. Unfortunately, no one can tell us definitively what that "something else" is, although people sell a great number of books by trying to do just that. What we can observe are trends that are forming, shifting, or being replaced. Thomas L. Friedman talks of globalization and the democratization of information.[8] Thomas P. M. Barnett talks of the core, the gap, and disconnectedness.[9] Fareed Zakaria speaks of the "democratization of violence."[10] With this as a backdrop, Secretary of Defense Donald H. Rumsfeld frames the national security challenge, initially called the Global War on Terror, as a "struggle against violent extremism" independent of whether the perpetrator is a nation-state or a terrorist group.[11] This struggle is marked by the lack of a clear beginning and the nature of the ending is not yet defined. However, we have been engaged militarily since 1990 with no prospect of disengaging any time soon.

The "struggle against violent extremism" presents new challenges for our established national security framework of assure, dissuade, deter, and defeat. The current Quadrennial Defense Review (QDR) has defined a set of four challenges to overlay the assure, dissuade, deter, and defeat framework. This set of four challenges consists of traditional challenges, catastrophic challenges, irregular challenges, and disruptive challenges.[12] Together the framework and QDR construct translate into new challenges across the entire spectrum of Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, and Facilities as it is applied within the four operating mediums of land, sea, air, and space. Since our ability to predict the future is poor at best, Secretary Rumsfeld wants capabilities that can be tailored for a wide variety of operations. These capabilities would, for example, look a lot more like Legos™ than an Erector Set™, that is, a rapidly adaptable, highly flexible force able to meet any challenge. Lest we be lulled into focusing solely on a single operating medium, I would like to point out that military operations may, on rare occasions, be accomplished solely by a single service, but they are no longer accomplished in a sin-

Air Force

TOW missile fired at building harboring Sadam Hussein's sons Qusay and Uday in Mosul, Iraq, on 22 July 2003.

AF Public Affairs

Special Operations Forces' new skills in Afghanistan.

gle operating medium. From self-defense to deep offensive operations all permutations can be seen: air power supports land and sea power, land and sea power support air power, and space supports everyone just as they support space power. Of course, none of this comes for free. Painful choices are ahead of us. This new force must be built while the existing force is fully engaged. National priorities also shift as they have this year due to storms named Katrina and Rita wreaking havoc with the national economy, budgets, and people's lives. Just recently, the US Air Force was told to find $2.1 billion to remove from its FY 2007 budget.[13] This is probably the first of several more FY 2007 budget reductions.

Operational Challenges

Drilling down a layer to look at the National Security Space environment, we find ourselves facing a new world. We face a world where the "democratization of information" places tools, formally reserved for a select few nation-states, in the hands of any individual with a credit card.[14] These tools are not limited to combat support capabilities such as satellite communications or overhead imagery and associated analysis, but combat capabilities such as Global Positioning System (GPS) jammers are also available on the international arms market.[15]

AF AIA

Aviaconversia GPS Jammer.

There are at least three implications that can be drawn from the new environment in which we find ourselves. First, we need to think through what "control of the high ground" means and understand the implications of that framework. Second, we need to think through and develop capabilities to deny others the use of the "high ground." Third, we need to think through and practice reestablishing control of the "high ground."

Although there has been extensive dialog on some parts of those questions, some people still ask why these questions need to be addressed. After all, availability and actual use can be a long way apart. Should we still believe space is a sanctuary where only nation-states might "inadvertently" cause or experience "anomalies"? The first publicly acknowledged "space skirmish" was fought in 1997 between Tongasat, the national satellite operator of the Kingdom of Tonga, and Indonesia.[16] Tonga and Indonesia both claimed the orbital slot located at 134 degrees East. APT Satellite Company based in Hong Kong placed Apstar 1A into the slot, which they leased from Tongasat. In response Indonesia jammed Apstar 1A. Note that in this "skirmish" a commercial company's asset was targeted and the commercial company was not based in either Indonesia or Tonga. More recently, Iraq tried to jam GPS receivers as part of their defense of Baghdad.[17] Space is not a sanctuary. Space systems are targets.

Space Acquisition: "Success – the only thing they pay us for"[18]

All of this brings us to the topic of space acquisition. In focusing on space acquisition, there are two questions I would like to address. The first question is: Have we been successful in the past? The second question is: How do we position ourselves to be successful in the future?

The answer to the first question hinges on the definition of "success." Clearly, space capabilities have made a huge difference in the way we conduct military operations. However, the question "have we been successful in the past" could be reworded "did we fail our way into today's capabilities so vital to our ability to defend this Nation?" The latter phrasing seems ludicrous, but some people define success in terms of operational effectiveness while others define success in terms of cost and schedule. I do not choose to define it as only one or the other because there must be a balance. Either one without the other is not useful over the long-term. I prefer to define success as delivering what we promised and promising what we can deliver. That definition has two parts to insure the bar isn't set too high or set too low. The definition of success cannot be strictly mission oriented. Cost and schedule are also promises made.

By this definition have we succeeded? Bluntly, the answer is: It's a mixed bag. From a mission standpoint we have indeed succeeded, often beyond our wildest dreams. The poster child for incredible success is clearly GPS. Unfortunately, the Minuteman program, Defense Support Program (DSP), Defense Meteorological Satellite Program (DMSP), and others have also over the years quietly exceeded all initial expectations. However, those mission successes may have been "pearls of great price." From the standpoints of cost and schedule we have had few, if any, successes. As far as many people are concerned we have made little headway since the Packard Commission Report in 1986.[19] Cost overruns and schedule delays hurt us in many ways. They cost us credibility. They exact significant opportunity costs. The ripple effect across the US Air Force of significant space program overruns creates a huge amount of uncertainty among other programs. In this interdependent world, the impacts of major schedule slips in a single program, a source of consternation in the past, now have the potential to wreak havoc on several other programs. Most importantly, schedule slips can have a cost measured in lives. We are at war and should never forget that.

Given this, how do we position ourselves for future success? Clearly, the outcome of the current acquisition reform studies will have an impact. As stated earlier, those studies will report out over the next several months. Separate from those studies, I believe there are several issues that we need to address in the near-term if we are to build the strong foundation spoken of by General Lord. None of these issues deal with the specific structure of the DoD acquisition process. Therefore, we do not need to wait to begin.

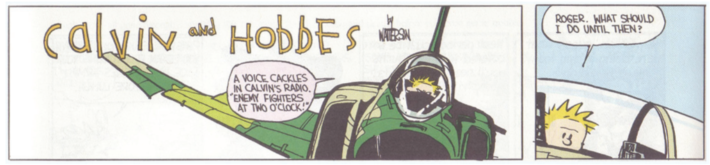
The first issue can be summed up as, "know our business." This should elicit the big "well duh!" from everyone. However, I ask you to consider the following:

- More than once I have come across lieutenant colonels in positions of authority who hold a level 2 certification, yet have no idea how to even develop a schedule.
- A number of our people lack an understanding of the basic "first principles" of science, yet ours is the most technical of missions.
- Our people identify with their job first and being a member of the Air Force second.
- Our retention rates to major are atrocious.[20]

Each of these contribute to a lack of understanding that impacts our ability to accomplish our mission, but we can fix this. Some actions are already in place and underway such as the development of the Space Cadre and early operational tours for acquisition professionals. I propose there are additional actions and options available to us.

1) We need to explore training and educational options to accelerate the pace of learning and gathering of experience. We should be working with the electronic gaming industry to develop interactive simulations that expand on the SimCity™ and SimEarth™ concepts. Options would allow engineering and programmatic choices and consequences to be played out over the life cycle of the systems and programs.
2) We need to train and bring enlisted personnel into the ranks of the acquisition professionals. Two factors converge to make this an imperative. First, many space operations positions previously held by officers are now held by enlisted members. Without enlisted billets in the acquisition corps, the cross-flow between operations and acquisition has been reduced dramatically. Second, we have the most highly educated NCO corps in the history of the Air Force. We need to take advantage of both their experience and their education.
3) We need to have discussions with appropriate industry organizations such as the National Defense Industrial Association concerning retention. The Air Force took a similar approach in the mid-1990s when discussions over pilot retention were held with the airline industry. At that time, the airline industry could have stripped the Air Force of pilots and still not filled all their vacancies. Just as Air Force pilots are sought after by the airline industry so our acquisition professionals are sought after by the defense industry.
4) We need to encourage acquisition professionals to deploy even if it is not into an acquisition billet. Deployments offer the opportunity to connect with the Air Force, other Services, and coalition partners that acquisition professionals do not often have. A deployment in some aspects should be considered a military variant of the "Education with Industry" program.

The second issue is communication. Communication is an issue not only internal to the military, but also between the military and industry. As the military has drawn down since the end of the Cold War and the older veterans have retired from industry, the number of people in industry with military experience has plummeted. We in the military used to speak a more commonly understood language. Basic concepts did not have to be explained, only merely expanded upon, as new capabilities were discussed. I propose we implement a "Blue Two" variant for space acquisition and operations not only with the standard cast of companies, but with companies outside of our traditional contractor base, as well as colleges and universities.[21] The space variant of Blue Two should also look at broadening participation from just senior level program managers and designers to more junior level personnel.



Calvin and Hobbes (c) 1988 Bill Watterson. Reprinted courtesy of the creator and Universal Press Syndicate. All rights reserved.

The third issue is a lightning rod that elicits strong emotions among those who were in acquisition from the late 1980s through the mid to late 1990s in part because it is tied to "better, faster, cheaper."[22] The issue is our current approach to the cost of launch. In my opinion, the approach we have chosen to respond to the cost of launch is unsustainable. It is unsustainable from a military perspective and it is unsustainable from an industry perspective. The path we are currently on follows death spiral logic, which runs as follows:

- Launch is expensive so we levy as many requirements as we can onto a system.
- Launch is expensive so we want the satellites to function on-orbit for a long period of time. That amount of time is now sometimes measured in teens versus single digit years.
- The net result is we do not build a lot of satellites, nor do we launch often. Therefore, we have difficulty maintaining a skilled cadre in the military and in industry. We also have a tough time responding to failures, regardless of whether they are launch failures or on-orbit failures, as well as meeting the changing needs of the combatant commands.
- The net effect is we feel compelled to pile an increasing number of requirements onto the few space systems we maintain. Thus, we complicate the design effort, lengthen the time from start to delivery, and bet the farm on systems living longer on orbit than predicted.

Combine that with less experienced personnel and the other thousand cuts the acquisition corps has experienced over the past decade and we get to where we are today.

Let me lay out a challenge. We have been asking how we get the launch cost per pound down. Are we asking the wrong question? Cost per pound is pretty easy to measure, but that does not make it the right metric. Capability counts. What is the right metric that captures the value of a constellation, a satellite, a system, and so forth? The metric should drive us toward the desired end state thus enhancing value. What is the right metric? I do not know the answer, but we must have these types of discussions now if we are to make good on the promises inherent in using space as an operating medium, as well as making operationally responsive space a reality.

The fourth and last issue I would like to address is the coming technical environment. This environment is going to be driven by interdependent, cross-discipline concept of operations and agile, adaptive adversaries. In recognition of this, Dr. Marvin Sambur, former Assistant Secretary of the Air Force for Acquisition, often spoke of the need for "robust systems engineering."[23] Dr. Sambur defined "robust" to be "insensitive to variability in manufacturing and use, and that are inherently scaleable/expandable/supportable."[24] That said, no single design and no single machine can be made infinitely robust. Robustness, to mix metaphors, is a function of the sum of all Legos™. This thought drives the concepts of net-centric and enterprise.

However, currently our ability to accomplish basic systems engineering is mediocre at best and systems engineering for the net-centric environment or at the enterprise level does not exist except at a rudimentary level. Efforts are underway to remedy our concerns about our basic systems engineering capabilities. While these efforts are mandatory they are not sufficient. We need to initiate efforts to document and teach the state of the art, such as it is, of systems engineering in a net-centric environment and systems engineering at the enterprise level. Currently, we are at the frontier of those disciplines. We also need to explore what those concepts and engineering disciplines bring to our concerns from ground-based space situation awareness systems to on-orbit operations.

There is one other aspect of the technical environment I would like to highlight before I close this article. To repeat an earlier statement of mine, this environment is going to be driven by interdependent, cross-discipline concept of operations and agile, adaptive adversaries. Yet, in my opinion, we, including the aerospace industry, have slipped into the "not invented here" syndrome. I often hear "space is different." Yes, it is different in a variety of aspects, but I think we overplay our hand. We need to stay connected to what is going on in other industries and be prepared to adapt all manner of ideas to our needs. For example, what can we learn from the work being done in telemedicine? Until recently, telemedicine was limited to only the generation or transfer of information such as X-rays. That limitation is about to disappear. The first major trans-Atlantic "telesurgical" operation has already occurred. The surgeon, located in New York, used a remotely operated surgical robot arm to remove the gall bladder from a patient in eastern France.[25] The techniques and procedures will help bring specialized care to areas where it is currently not feasible to provide such care on a routine basis. Telemedicine will have to resolve such issues as trades between man-in-the-loop and software, communication lag times, the equivalent of "pilot induced oscillations," and so forth. Examples can also be drawn from the financial, electronic gaming, and other industries as they seek to maximize "value" in an increasingly interconnected and interdependent world. We should actively seek out their "lessons learned" and look for areas to cross apply either directly or modified to suit our needs. We should also encourage non-traditional teaming amongst our contractors.

In Closing

The conclusion to this macro view is straightforward. Expectations are high and money is tight. When all is said and done, that's not necessarily a bad place to be. To quote Ernest Rutherford, "We didn't have any money so we had to think."[26] There are a lot of very smart people currently looking at acquisition reform, but we should not wait passively for their conclusions and recommendations. We simply cannot continue to do business the way we have in the past. We need to address questions such as those raised in this paper, focus on what we can do ourselves, and get on with it. The trick is what to keep from the past, what to replace, and with what do we replace it. We are indeed in a crisis. The rest of the world is rapidly moving on and we are at war. However, it is interesting to note that the Chinese character for crisis, "wēijī," has two syllables. The first syllable, "wēi," stands for danger. The second syllable, "jī," stands for "the crucial point (when something begins or changes)."[27] Mindful of the dangers this Nation faces, we are indeed at a crucial point. We are the best air and space force in the world. It is up to us to keep us there.

危机

Chinese for crisis, wēijī.

Notes:

1 "Upcoming Spotlight," *Aviation Week & Space Technology*, 31 October 2005, 21, attributes the comment to Sen. McCain. The comment was made as part of remarks recently given at the Heritage Foundation.

2 Baker Spring, "Congressional Restraint is Key to Successful Defense Acquisition Reform," Backgrounder #1885, The Heritage Foundation, 19 October 2005, www.heritage.org/Research/NationalSecurity/bg1885.cfm (accessed 29 November 2005).

3 Lt Gen (USAF, retired) Kadish, Project Chair, Defense Acquisition Performance Assessment Project, www.dapaproject.org

4 Tamar Mehuron, "Space Almanac 2005," *Air Force Magazine* 88, no. 8, August 2005, 46.

5 Air Force Association, Legislative update on 27 October 05, www.afa.org; "Pentagon leadership has told the respective branches that they will need to eliminate $8 billion from their FY 2007 budgets. The individual cuts are as follows: $2.3 billion for the Army, $2.2 billion for the Navy, $2.1 billion for the Air Force, and $900 million for DoD-wide accounts. Additional cuts are expected to follow in the near future."

6 General Lance W. Lord, "Why America Needs Space: The Prerequisites for Success," *High Frontier* 2, no. 1 (2005): 2. General Lord stated his Command's top three priorities are as follows: (1) Continue our emphasis on ensuring Space Superiority and Provide Desired Combat Effects for Joint Warfighting, (2) Maintain a safe and secure Strategic Deterrent Capability and providing a means for Prompt Global Strike, (3) Continue efforts to develop Cost-Effective Assured Access to Space."

7 Ibid.,3.

8 Thomas Friedman, *The Lexus and the Olive Tree*, New York, NY: Anchor Books, 2000, (chap. 4). Thomas Friedman has authored multiple books on globalization to include *The Lexus and the Olive Tree* and *The World is Flat*.

[9] Thomas P. M. Barnett, *The Pentagon's New Map*, New York, NY: G.P. Putnam's Sons, 2004.

[10] Ibid., 34.

[11] Donald H. Rumsfeld, Secretary of Defense, (remarks, Hyatt Regency Hotel, Philadelphia, PA, 25 May 2005), www.defenselink.mil/speeches/2005/sp20050525-secdef1461.html (accessed 29 November 2005). "What, then, is the strategy for winning this struggle against violent extremists?"

[12] Headquarters US Air Force Future Vectors, "Assuring Joint Air & Space Dominance in the 21st Century," 6 – 9. Additional information is available at www.qr.hq.af.mil/QDR_XPXZ_Products.htm.

[13] Air Force Association.

[14] Example 1: Satphonestore, communications services, www.satphonestore.com, A Thuraya handset is available for $649, Airtime costs "$1.14/min Iraq to US" and "$1.14/min Iraq to Germany," Prepaid phone cards for an Iridium phone can be bought for 20 min/$25 and 550 min/$500. Example 2: Space Imaging, Inc., radar and optical imagery products, www.spaceimaging.com/products/default.htm; and Orbimage Inc., www.orbimage.com.

[15] Adam Hebert, "Towards Supremacy in Space," *AFA Magazine* 88, no. 1 (January 2005). "…For example, GPS jammers are available on the open market for $38,000 and satellite communications "noise-makers" can be bought for $7,500 …."

[16] "Tonga Accuses Indonesia of Jamming Satellite Signals," *Satellite News* 20, no. 9 (3 March 1997) Phillips Business Information, Inc., copyright 1997.

[17] Liza Porteus, "Russian Dealers Provide Iraq with Supplies," *FoxNews.com*, 23 March 2003, http://www.foxnews.com/story/0,2933,81917,00.html (accessed 29 November 2005).

[18] One of Colonel Jim Mannen's favorite sayings when I worked for him in the mid 1980s and early 1990s.

[19] NDU Library, Reports of the President's Blue Ribbon Commission on Defense (1986), http://www.ndu.edu/library/pbrc/pbrc.html (accessed 29 November 2005). The Blue Ribbon Commission on Defense Management, commonly known as the Packard Commission, was established by President Reagan in 1985 to assess what was wrong with DoD acquisition and provide recommendations. Mr. David Packard, former Deputy Secretary of Defense, was the commission chair.

[20] An informal poll taken at the Space and Missile Center in 1997 indicated that our retention rate for engineers was approximately 12%. AF data since that time does not show a significant change.

[21] The Air Force Blue Two program introduces industry's top design engineers and program managers to the day-to-day constraints Air Force maintainers face on front-line operations bases.

[22] The Packard Commission's final report stated, "With notable exceptions, weapon systems take too long and cost too much to produce. Too often, they do not perform as promised or expected." This led to the bumper sticker "better, faster, cheaper."

[23] Dr. Marvin Sambur was the Assistant Secretary of the Air Force for Acquisition from 2001 to January 2005. "Robust systems engineering" was one of the five pillars of his Agile Acquisition initiative. The other four pillars were collaborative requirements, technology transition, seamless verification, and expectation management. Additional information: Agile Acquisition, http://ax.losangeles.af.mil/axd/agile_acq/agile_acq.htm (accessed 29 November 2005).

[24] Ibid.

[25] TelMedPak Telemedicine, "World First Major Tele surgery Operation," http://www.telmedpak.com/telemedicinenews.asp?a=2124 (accessed 29 November 2005).

[26] Ernest Rutherford was a Nobel Prize winning physicist who lived from 1871-1937.

[27] Victor H. Mair, "danger + opportunity ≠ crisis," Pinyin.info., http://www.pinyin.info/chinese/crisis.html (accessed 29 November 2005). Victor H. Mair is a professor of Chinese language and literature at the University of Pennsylvania. Denis Mair and Zhang Liqing contributed to the essay.

Brig General Katherine E. Roberts (BA, Physics, Indiana University; MS, Space Technology, John Hopkins University, Maryland) is Principal Director for Forces Policy, Office of the Deputy Assistant Secretary of Defense for Forces Policy, Washington, D.C. She is responsible for policy development and recommendations for senior Department of Defense officials concerning space, missile defense, offensive and defensive strategic capabilities as part of the new triad, and warfare based on new technologies.

General Roberts entered the Air Force in 1977 through the ROTC program at Indiana University where she was a distinguished graduate. Her assignments include space operations, acquisition of space systems and staff work. She was a manned space flight engineer, the program manager of a major acquisition program, and has served on the staffs at major command and unified command headquarters, Office of the Assistant Secretary of the Air Force for Space, and the Joint Staff. She served as the Vice Director of Operations at US Space Command and the Vice Director for Space Operations at the new US Strategic Command for the run-up and execution of Operation IRAQI FREEDOM. Prior to assuming her current position, General Roberts was Commander, Command and Control, Intelligence, Surveillance and Reconnaissance Systems Wing at Hanscom Air Force Base, Massachusetts.

Moving Beyond Acquisition Reform's Legacy

**Brig General Ellen M. Pawlikowski, Director,
Military Satellite Communications Joint Program Office,
Space and Missile Systems Center**

Since 11 September 2001, our Nation has been at war, the Global War on Terrorism. It has been a challenging time for our Nation and for our military forces and, like so many other times in our history, our Air Force, Army, Navy, and Marines, are working together to bring awesome military capabilities to the fight against terrorism. Led by Air Force Space Command (AFSPC) and its Space Superiority capabilities, space brings an increasingly important advantage to that fight. Space is providing the backbone for Joint Warfighting Capability and our Nation's warriors have grown to depend on space forces to provide communications, intelligence, surveillance, reconnaissance, and global positioning on demand.

This reliance of the joint warfighter on space has focused an unprecedented spotlight on space acquisition. Our warfighters need improved space capabilities and they want it now! At the same time, space systems acquirers are heavily engaged in their own battle - the fight to recover from the unintended consequences of a decade of acquisition reform in the Department of Defense (DoD).

The 1990s were a time for grand experiments in DoD acquisition. In attempts to deal with decreasing resources coupled with increasing requirements, the Department embarked on "acquisition reform." The conventional wisdom was that our acquisition of new weapon systems was taking too long and costing too much because we were stifling creativity and over burdening the industry. We had too much government oversight and micromanagement. Overly restrictive military specifications (MILSPECs) and standards were driving inordinate costs and extended schedules. At the same time, the DoD was under Congressional pressure to reduce the number of "buyers" in the department. In response to this pressure, the DoD acquisition force was reduced by 50 percent.

The answers to these challenges were initiatives such as Total System Performance Responsibility (TSPR) to industry and the banishment of MILSPECs and standards. Aggressive cost estimates were applied and competition was focused on the lowest bidder to challenge creativity and "do more with less." These initiatives were ambitious, but unproven, and often employed in an effort to wish away very real problems.

Unfortunately, for space programs, the consequences of these initiatives took a few years to surface. At the turn of the new century, program after program found itself facing problems that could be traced back to these initiatives. Cost overruns resulted from the aggressive cost estimates and associated higher risk expenditures. Schedules stretched as programs experienced budget cuts from competing programs, Congressional reductions in appropriation requests, test and integration failures that were traced to the lack of rigorous systems engineering or inadequate standards and specifications. The limitations of TSPR surfaced as the Air Force struggled with the unforeseen complexity of horizontal integration across weapon systems and components.

The problems were universal within the DoD, but space systems were hit particularly hard. Due to technical complexity and unique manufacturing challenges, space programs were more severely impacted by the lapses in systems engineering discipline and standards. The longer development times for space systems meant it took longer for space programs to enter into test where the negative aspects of acquisition reform initiatives were most likely to surface. These unique features of space systems made the problems even more acute than for aircraft, ships, and tanks.

Recognizing the need for a comprehensive new look at the problem, the space acquisition community called in a team of crack engineers and acquisition experts led by Mr. A. Thomas Young under the charter of the Defense Science Board and the Air Force Scientific Advisory Board, to triage our ailments and make recommendations for recovery.

The Young Panel succinctly characterized the high level challenges facing the space acquisition community:

1. US National Security is critically dependent upon space capabilities and that dependence will continue to grow.
2. Five factors have had a devastating effect on space program success:
   a. Cost has replaced mission success as the primary driver in managing space development programs
   b. Unrealistic estimates lead to unrealistic budgets and unexcutable programs
   c. Undisciplined definition and uncontrolled growth in systems requirements increase cost and schedule delays
   d. Government capabilities to lead and manage the space acquisition process have seriously eroded
   e. Industry has failed to implement proven practices on some programs
3. The space industrial base is adequate to support current programs although there are long-term concerns.

The Young Panel's assessment was taken to heart by the Space and Missile Systems Center. We have aggressively worked to address the problems identified by Mr. Young. We have done this both from an overall center perspective and also with the individual programs. We have faced the challenges of fixing programs birthed in the acquisition reform era. We have initiated new programs on the right footing.

In the Military Satellite Communications (MILSATCOM) Joint Program Office (MJPO), we have taken on these challenges as we work to provide the DoD's satellite communications systems. But, in addition to our focus on reversing the direction resulting from acquisition reform, we have also taken on the unique MILSATCOM challenges posed by our joint warfighters:

1. The increasing demand for more bandwidth and connectivity. The joint warfighting concepts of today's fight rely on distributed operations requiring the dissemination of large amounts of information wherever needed. This real-time situation awareness means that our warfighters have instantaneous communication anywhere in the world twenty-four hours a day, three hundred and sixty-five days a year.
2. The impact of new and emerging technologies and reduced technology cycle times. New information system technologies have revolutionized the way we live our lives. We know that application of these technologies to military operations can dramatically increase effectiveness and save lives. MJPO's challenge is to strike the right balance between incorporation of the latest relevant technologies into our space programs and minimization of the risks caused by the use of immature technologies.
3. The impact of concurrent development and the Global Information Grid. No longer can SMC afford to design and build stove-piped systems. MILSATCOM is so extricably integrated into warfighting systems that we must design our systems to accommodate the changes made to other programs and concepts. Conversely, those programs, including future weapons programs, are absolutely dependent on the increased MILSATCOM bandwidth our programs will deliver.
4. Managing legacy capability during the acquisition of new systems. The US military cannot afford to throw away existing satellite communication systems when we introduce a new capability. Instead, the MJPO must ensure that our systems are compatible with existing communication systems used by warfighters today without unduly degrading the new capabilities promised by tomorrow's systems. We must also meet the considerable challenge of providing a seamless transition from the old to the new systems with minimal warfighter impact.

In the remainder of this paper, I would like to share with you how the MILSATCOM Joint Program Office is addressing the issues identified by the Young panel and the challenges posed by the joint warfighting arena. Specifically, we'll look at two programs, the Advanced Extremely High Frequency (AEHF) and the Transformational Satellite Communication System (TSAT) programs. The AEHF program was birthed in the acquisition reform era and provides a good example of how the space acquisition community is addressing existing program problems. TSAT is a new program birthed since the Young Panel review and therefore has had the opportunity to "do it right" from the beginning. These two examples give us the opportunity to look at the full spectrum of challenges facing space acquisition.

Advanced Extremely High Frequency (AEHF).

Advanced Extremely High Frequency (AEHF) Program

The AEHF system is a joint service satellite communications system that provides global, protected, and jam-resistant communications for high-priority military ground, sea, and air assets. The system currently consists of three satellites in geostationary earth orbit; a distributed Mission Control Segment, Mission Planning Element; and a suite of multi-service terminals. It will provide 10 to 100 times the capacity of the 1990s-era Milstar satellites. A full constellation of four satellites (3 AEHF plus one TSAT) would provide continuous 24-hour coverage between 65 degrees north and 65 degrees south latitudes. AEHF will allow the National Command Authority and the Unified Combatant Commanders to control their strategic and tactical forces at all levels of conflict including general nuclear war and supports the attainment of information superiority. AEHF will provide connectivity across the spectrum of mission areas, including land, air, and naval warfare, special operations, strategic nuclear operations, strategic defense, theater missile defense, and space operations and intelligence.

AEHF was birthed as an acquisition reform program. It entered the 21st century plagued with the devastating effects of the acquisition reform era. The program's first contract was a commercial fixed-price contract with little oversight by the government and without the application of MILSPECs and standards. The budget for the program was determined based on the available funding, not on requirements. Both the government and the industry team accepted the "challenge" to deliver a capability based on a dictated bottom line price. The warfighter Systems Requirements Document and the contractually binding specification were never reconciled. Warfighter expectations were not balanced with the realities of the programs budget and schedule and did not reflect an assessment of the state of technical maturity. Further, the government team put in place to oversee the program was streamlined. A large percentage of the team consisted of new, junior officers ill-equipped to manage a program as complex and extensive as AEHF.

The government and industry team have made steady progress in addressing all the devastating impacts of the acquisition reform era. The contract was restructured to a more traditional cost-plus defense contract that included the application of certain key MILSPECs and standards. The budget for the program was adjusted upward to capture the true costs and has grown from $4.8 billion to $6.1 billion. This increase does not so much reflect cost growth as a more educated recognition of the true cost of the capability needed by the warfighter and to address new requirements associated with the emerging DoD encryption key management architecture. Requirements management continues to be a challenge for the program and efforts are underway with HQ AFSPC to impose more discipline in requirements changes from the AEHF users in all services. New requirements and requirement disconnects will be evaluated cooperatively between the program office and the user community. The process is focused on controlling cost increases by controlling requirements growth.

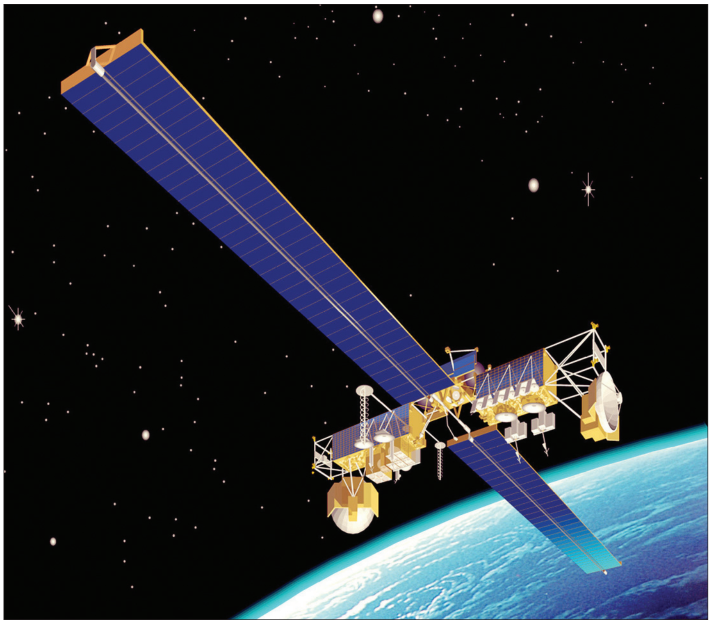
The AEHF program will contribute significantly and immediately to meeting the warfighter desire for more bandwidth. With single satellite capacity greater than the entire Milstar constellation, the AEHF system will increase the DoD's protected communication capability by an order of magnitude. It will enable the Air Force to pass Air Tasking Orders in seconds as opposed to over an hour under Milstar I. The Army will be able to pass an annotated 8x10 image in just over 20 seconds versus several minutes using Milstar II. AEHF will provide a vast improvement to the joint warfighters' ability to prosecute distributed operations and attain a higher level of situation awareness.

To achieve these levels of performance, and launch compatibility with an Evolved Expendable Launch Vehicle medium class launch vehicle, the AEHF program has integrated a number of state-of-the-art technologies. We have taken on the challenge of balancing the desire to apply the latest in technologies with providing sufficient time to allow technologies to mature. The program has leveraged commercial technologies, heritage Milstar technology, and Independent Research and Development products to achieve the AEHF mission needs. These technologies include: Lockheed Martin commercial A2100 bus providing cost savings through reuse and reduced weight to achieve launch vehicle requirements; higher solar array output to meet higher power needs, providing 27.5 percent efficiency and reduced weight to achieve launch vehicle requirements; a new Xenon propulsion system providing increased payload capability and reduced weight to achieve launch vehicle requirements; single-board computers leveraging commercial advances to provide increased capability and reduced weight to achieve launch vehicle requirements; phased array technologies providing increased capability to meet mission requirements; and new microelectronics for improved front-end performance and reduced weight to achieve launch vehicle requirements. The new technologies employed have gone through a rigorous risk reduction program, which was initiated during the early technology development studies and system definition (SD) phase of the program. As a result, the lowest technology readiness level (TRL) assigned to an AEHF system or subsystem is 6, which is defined as demonstration of the system/subsystem model or prototype in a relevant environment (ground or space).[1] The Milstar and other heritage technologies utilized on AEHF have a TRL of 8 and 9, as they have been "flight qualified and/or flight proven."

The program further mitigated program risk and reduced development schedule timelines through the application of engineering development models (EDMs). These EDMs are early hardware and software products for the critical components of the AEHF payload. They are tested in a disciplined process, building up from the component through sub-system to system level. They provide an invaluable tool for reducing risk and gaining early confidence in system components. The program combines the use of these EDMs with a disciplined technology maturation/risk management process. These tools and techniques are allowing the AEHF program to leverage the latest technology into our satellites with lower risk and higher mission assurance.

One of the major challenges to the AEHF program is concurrent development. Our ability to bring capability to the joint warfighter requires that we synchronize multiple developments simultaneously. This challenge is even greater because the individual components are developed by different DoD program offices. The MILSATCOM Joint Program Office at Los Angeles AFB manages the satellite and ground control segments for AEHF. The AEHF command and control terminal is part of the Family of Beyond Line-of-Sight Terminal program under-development at the Electronic Systems Center. The cryptological hardware development for the satellites and the terminals is managed by the National Security Agency. The three services each have their own AEHF terminal development programs. Finally, the preparation for operations and training is under the direction of the Air Force 50th Space Wing. Coordination of all these efforts is absolutely critical to successful fielding of the AEHF system.

The program office has implemented a number of actions to ensure coordination of these concurrent developments. The MILSATCOM Configuration Board was established to provide a single control point for each program's technical and schedule baseline. As each program experiences fact-of-life changes or technical-challenge changes, all of the program managers have visibility into these changes and can contribute to developing plans to deal with these changes. In addition to cooperative configuration control, the AEHF program conducts quarterly EHF Systems Acquisition Councils (ESAC). The ESAC provides an excellent forum for program managers from across the EHF product line to share information and coordinate actions. The EHF product line includes not only the AEHF satellite/ground system, but also the crypto, Satellite Control Network C2, and terminal programs required to make the capability a reality.



Milstar.

Maintaining compatibility with Milstar is a top priority for the AEHF program. The warfighter will continue to use the Milstar terminals and network long after AEHF is fielded. To ensure changes to the Milstar constellation and terminals are accommodated within the AEHF program, Milstar changes are tracked by the MILSATCOM configuration board and evaluated by the AEHF program to determine how these changes impact the AEHF system. As the satellites and ground system mature; it will become increasingly more difficult for AEHF to change to accommodate Milstar changes, so close cooperation between the AEHF program office and the 50th Space Wing will be an absolute must to address synchronization of the operational Milstar configuration and the fielded AEHF system.

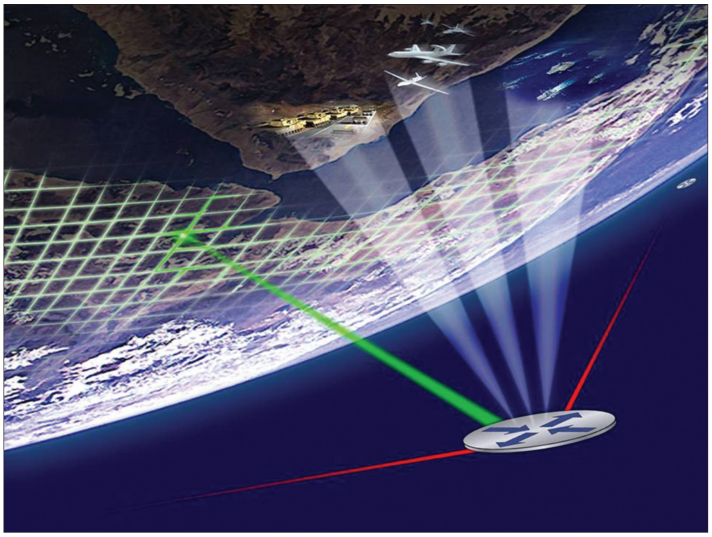
The competence of the government team to manage AEHF and other space programs is a major focus area for SMC. SMC has recognized the need to train and educate our junior work force. The SMC Acquisition School has been operational for 12 months and its curriculum consists of courses in all aspects of acquisition. As new engineers and program managers come to SMC, their first stop is the SMC Acquisition School. To date, 43 individuals have been trained in this program. In addition to the school and other educational opportunities, SMC has focused serious effort to provide SMC's engineers and program managers guidebooks and instructions on most of the critical acquisition processes. There has been an increased focus on mentoring by senior acquisition professionals as well as efforts to maximize special employment programs and engage in active recruiting. Assignments have been extended for key program leaders in order to maintain continuity. SMC is still challenged by a junior work force and an insufficient number of qualified senior acquisition professionals, but we are on a steady recovery path and the AEHF program has benefited from these SMC initiatives.

The last issue identified by the Young Panel that the AEHF program has tackled, is the implementation of proven practices by Lockheed Martin. Lockheed Martin and the aerospace industry have partnered with SMC to focus efforts on ensuring 100 percent mission success. Lockheed Martin has revised its command media with focus on product quality, and incorporation of safeguards to prevent errors and performance issues. The command media incorporates lessons learned and guidelines to compensate for streamlined application of acquisition MILSPECs and standards. In addition, Lockheed Martin has established a dedicated office that reports directly to the office of the President to ensure compliance to processes and procedures, evaluating program execution, and product qualification. Mission Success and Product Assurance gated entry and exit points have been implemented for the products developed and major program milestones to further ensure product development compliance. Mission Success coupled with Product Assurance has increased the vigilance and rigor in process compliance and instilled increased discipline in the program environments. To further ensure product quality and mission success, Lockheed Martin has implemented a certification program, Certified Product Engineering (CPE), for product engineers to ensure appropriately trained personnel are developing products and that disciplined processes and procedures are being implemented. All Lockheed Martin products for the AEHF program are developed by CPEs, who have been assessed by Lockheed Martin Space Systems Company engineering office. Through these organizational, process/procedural, and training efforts, Lockheed Martin has ensured that proven practices are incorporated in all products.

The AEHF program was born in the pre-9/11 and acquisition reform era and as such, has had to make some significant adjustments. But, those adjustments have been made. The AEHF program of 2005 is focused on Mission Assurance as the top priority. Its execution is on a solid foundation of both government and industry best practices. We still struggle to overcome the long-term effects of acquisition reform but we have the right team and management processes in place to succeed. Our success is critical to providing the capabilities required by today's joint warfighter; that is a capability that provides worldwide communication enabling distributed operations with real time situation awareness in a horizontal fully integrated warfighting effect.

Transformational Satellite Communication System (TSAT)

Unlike AEHF, the TSAT program is a product of the post-acquisition reform era. As such, the program was structured to focus on mission success from initiation. This includes strong government insight of contractor activities; incorporation of MILSPECs and standards; and centralized systems engineering and integration. The TSAT system will provide even further increased bandwidth, data rate and full network connectivity with ground networks. TSAT, a network communications system for tactical and strategic warfighters, is an integral part of the Global Information Grid (GIG). The primary purpose of TSAT is to create a network system that connects the GIG to global users that are beyond the line-of-sight of the fiber-based, terrestrial GIG. The goal is to provide a capability for the end users



Transformational Satellite Communication System (TSAT) Concept.

to operate over the network just as if they were connected to the Internet on the ground, without having the communication path limiting their communications capability. This includes connectivity for disadvantaged users with small terminals, such as Communications-on-the-Move support. Additionally, the program incorporates the direct connection to airborne and space intelligence, surveillance, and reconnaissance platforms as source data to provide those DoD users with situation awareness and targeting data. Advances in space technology offering high data rate laser communications links and network services directly integrated with terrestrial packet switched (i.e., Internet-like) communications will help achieve this goal.

It is not hard to recognize how TSAT is addressing the 21st century warfighter's need for bandwidth and connectivity. The very heart of the TSAT's requirements is the Air Force, Navy, and Army's net-centric warfare concepts. TSAT's focus is to provide high bandwidth efficiently managed to provide the maximum possible connectivity to the joint warfighter operations. TSAT will provide another order of magnitude in capacity beyond AEHF. Times for relaying air tasking orders, visual imaging, and radar images will be less than a second, thus providing the first real opportunity for machine-to-machine closure of the fire control loop for modern, sophisticated weapons. In addition, for the first time our ground forces will have the ability to communicate while on the move, thus enabling real-time distributed operations worldwide.

TSAT is accomplishing this revolutionary step in satellite communication through smart management of technology maturity and application. From its inception, the TSAT program office has recognized the need to deliver the most advanced capabilities while minimizing the risk of introducing immature technologies. The TSAT program has invested in excess of $1 billion conducting risk reduction and SD activities. These activities are designed to ensure warfighter needs are translated into technical requirements, reflected in detailed system designs, and that the required technologies are ready for full scale development. A disciplined and rigorous technology maturation process is in place that includes independent validation testing using Massachusetts Institute of Technology (MIT) Lincoln Laboratory, a federally funded research and development center. These activities are designed not only to demonstrate component level TRL, but also integrated performance at the systems level. Using this process, the program has matured technologies to TRL 6 long before the program has entered full scale development, thereby significantly reducing program risk. In a recent review of TSAT, Mr. A. Thomas Young, complimented this effort and stated that he found the TSAT early investment in technology maturation in system definition "unprecedented."

Since TSAT is the space segment of the GIG, the integration challenges are more significant than on past space programs, which have been relatively "stove-piped." To meet this challenge, the TSAT program office has partnered with the wider GIG community to establish a common set of networking standards that will ensure end-to-end interoperability of all communication systems. This common framework is documented in the Net Centric Interoperability Document, which has been approved at the DoD chief information officer level.

The TSAT program has made addressing the issues identified by the Young Panel a central focus for the program. As stated above, mission success, risk reduction, and centralized systems engineering and integration have been incorporated from program initiation. In addition, great strides have been made in other areas including: improved cost estimating, and more rigourous independent assessments. One process highlighted as an SMC best practice is the TSAT Cost As an Independent Variable (CAIV) user forum. The CAIV process provides an excellent way to examine warfighter requirements in the context of cost. The CAIV user forum membership includes the services, joint staff USSTRATCOM and the combatant commands (COCOMs). The goal of the process is to deliver the most beneficial system, from a warfighter perspective, given budgetary constraints. To date, the process has resulted in significant cost savings while at the same time increasing utility to the end user.

Government leadership of a program like TSAT presents significant challenges. SMC is still striving to achieve the necessary level of expertise and manning to manage the TSAT program. Multiple strategies are being utilized to address this challenge including utilization of the Intergovernmental Personnel Act to bring in highly skilled engineers and managers from across the country, utilizing federally funded research and development centers in nontraditional roles, and heavy recruiting from industry to fill government civilian positions. The center has also made the program a high priority for military staffing, which has had a positive effect.

Finally, industry has brought their best to the table. As TSAT is currently in the risk reduction and SD phase, there are multiple contractors vying for the final development contracts. All have strived to integrate lessons learned from recent space programs, including incorporation of many Young Panel recommendations. Specific actions include more rigorous mission assurance processes; increased focus on program management and systems engineering; higher fidelity cost estimating with internal, independent reviews; and improved metrics tracking for early problem identification and reporting. The TSAT contractor teams have also embraced the programs risk reduction philosophy of early developmental testing both within the contractor facilities and at independent government testbeds. This will help ensure technologies are well understood before entering full-scale development and that performance versus cost trades are accurate. In the end, this will help the program office deliver capability to the warfighter on schedule.

Conclusion

In this paper, I have attempted to discuss the challenges faced by the space acquisition community in recovering from the acquisition reform era so that we can more effectively contribute to the global war on terrorism and meet increasing warfighter reliance on real-time information. Our joint warfighters are relying on space systems to be omnipresent. As space professionals, we must deliver the capability of today and tomorrow. We must provide the warfighter the means to exploit space to deliver effects to the battlefield. Space acquisition programs such as MILSATCOM must provide ever-increasing capability (i.e., bandwidth). We must be able to exploit the latest in technology without adding undue risk to on-time delivery of new capabilities. We must deliver systems that are fully integrated into effects capability even if that means leading multiple diverse programs within a concurrent development environment. This is our mission in support of our warfighters; failure is not an option.

The space acquisition community is postured to meet this mission. We will overcome the devastating effects of the experiments in acquisition reform in the 1990s. SMC has met that challenge by placing mission assurance as our top priority. We are reinvigorating our efforts to perform accurate cost estimating and budgeting. We have returned to disciplined systems engineering to include implementation of MILSPECs and standards and government ownership of accountability where appropriate. Strong efforts are underway to provide an educated and experienced work force to ensure the right level of government involvement and oversight in all of our programs. The aerospace industry has partnered with SMC and is returning to tried and true processes that are geared toward mission success. We still have work to do to completely recover from the effects of the 1990s, but SMC has made significant strides to do so. One thing is clear to us, we are 100 percent focused on delivering the world's best space effects for the US warfighter.

Notes:

[1] John C. Mankins, "Technology Readiness Levels," A White Paper, Advanced Concepts Office, Office of Space Access and Technology, NASA (6 April 1995); www.hq.nasa.gov/office/codeq/trl/trl.pdf

Brig General Ellen M. Pawlikowski (BS, Chemical Engineering, New Jersey Institute of Technology; PhD, Chemical Engineering, University of California at Berkeley) is the Director, Military Satellite Communications Joint Program Office, Space and Missile Systems Center, Los Angeles Air Force Base, California. Promoted to Brig Gen in June 2005, she directs acquisition planning, programming, budgeting, execution, and congressional activities for a $46 billion portfolio for military satellite communication systems including the Milstar constellation, the Defense Satellite Communications System, the Wideband Gapfiller Satellites Program, the Advanced Extremely High Frequency Program, the Transformational Satellite Communications System Program, the Global Broadcast Service Program, the Command and Control System-Consolidated Program, associated Air Force communication terminals, and mission control systems. She exercises the authority of the Air Force Program Executive Officer for Space in interacting with the Office of the Secretary of Defense, the National Reconnaissance Office, the National Aeronautics and Space Administration, the National Security Agency, and major commands.

General Pawlikowski has served in a variety of technical management, leadership, and staff positions in the Air Force and has served as Deputy Assistant to the Secretary of Defense for Counterproliferation in OSD. Her assignment prior to the MILSATCOM Joint Program Office was the Director, Airborne Laser System Program Office, Space and Missile Systems Center, Kirtland AFB, New Mexico.

SAS, the Cornerstone of Space Acquisition Success

Col James R. Horejsi
Chief Engineer, SMC and
Deputy Director, Systems Acquisition Directorate, SMC

What is the SAS?

The Space and Missile Systems Center's (SMC) Acquisition School (SAS) is a unique program taught at the only military space acquisition center in the Air Force. Located at Los Angeles AFB, California, it is an eight-week opportunity for recently-assigned lieutenants and civilians in the science, engineering, or program management career fields to gain hands-on experience in the acquisition process. Throughout the course, numerous classes are taught emphasizing the hands-on application of sound acquisition management practices to acquire, deliver, and sustain effective and affordable space and missile systems that meet or exceed our warfighter needs.

Origin and Significance

Historically, the education and training of Air Force program managers and engineers has been handled as a responsibility of the individual, to be generally accomplished in their spare time, via the courses provided by Air University, Air Force Institute of Technology (AFIT), and similar academic institutions. Manpower shortfalls and the high pace of activity in the program office, however, left little time to invest in education and training. Furthermore, the courses offered by those academic institutions do not address the unique requirements of space and missile procurement nor how to appropriately tailor the Department of Defense's standard acquisition approach. Inappropriately applying these acquisition principles to the space environment contributed to the launch failures in the 1997-99 time frame and many of the cost overruns and schedule delays encountered in space acquisition. Studies such as the Launch Broad Area Review, the Young Panel, and similar Congressional panels identified, among other things, the lack of adequate training and expertise among the space acquisition community.

In recognition of this need, Air Force Space Command (AFSPC) established the Space Professional Development Program (SPDP), consisting of Space 100, 200, and 300 to educate and train people who acquire, develop, sustain, and operate space systems within the Air Force. This did not address the unique needs of SMC however.

In 2004, I was tasked by the former SMC Commander, Lt General Brian Arnold to integrate the various education and training efforts to provide space acquisition personnel the tools they need to become the premier space acquisition force of the 21st century. The approach was simple. To the maximum extent possible, using courses currently available through Defense Acquisition University (DAU), AFIT, AFSPC's SPDP, and other institutions, establish the SMC Professional Training Program (SPTP) as part of the SPDP to directly address the unique needs of the SMC space acquisition workforce, both new and old. For those military and civilians new to space acquisition, SMC established the SMC Acquisition Schoolhouse (SAS), which along with Space 100, represents the first step in educating and training our space acquisition professionals.

Although relatively new, the SAS recently graduated its fourth class since starting October 2004, and has already received high marks for its success. With minimal resources and using personnel drawn from within SMC/AX, the SAS has demonstrated a dramatic payback in the productivity and character of its graduates in the space acquisition force at SMC. In recognition of the need to institutionalize the SAS, Lt General Michael Hamel, current SMC Commander, mandated the creation of a new three-letter organization to execute the SAS and the Continuing Education Program managed by the SPTP. He stated at a SAS graduation, "This is the future of the SMC and acquisition work force." Subsequent to that, he added, "SAS is a very good program and is long overdue." Other praise was voiced directly to Congress when General Lance W. Lord, Commander, AFSPC, said, "These courses re-emphasize a solid systems engineering approach."

The fifth session of SAS now basks in the collaborative effort drawn together by the SPTP. Government education and training agencies such as AFIT, DAU, and The Aerospace Corporation's Aerospace Institute have all cooperated to bring the finest in education and training talent and materials to bear. With guidance from the National Security Space Institute and in unison with the groundwork already set by Air Force Education and Training Command in their acquisition familiarization training,

Todd Sobel of ARINC

2nd Lt Tan Ngo prepares to launch the course's acquisition product at Edwards AFB, California.

2nd Lt Brian Yoder awaits launching the balloon-propelled device during launch countdown.

SAS also benefits from local functional training programs such as Contracting University (SMC/PKU), Financial Management University (SMC/FMU) and just-in-time training from SMC's Acquisition Center of Excellence.

Course Overview

The curriculum encompasses nine functional areas (developed from surveys of program office needs) selected to hone SMC's acquisition capabilities to better control costs, meet schedule, and achieve technical performance requirements. Highlights of the course include: Systems Engineering Tools, Risk Management, and Test and Evaluation; tours of launch and range facilities at Vandenberg AFB, California and Patrick AFB, Florida; and visits to local contractor manufacturing facilities. The heart of the SAS is the design lab, a hands-on approach that gives the students direct experience with the "how to" of acquisition. The design lab guides the students through an acquisition that starts with requirements definition and ends with an operational test and evaluation. The course emphasizes how a person in a SMC program office executes his/her job, given that space acquisition generally deals in small quantities of high value/high risk items (e.g., satellites). The students role-play various government and contractor positions in developing a real product using the guidelines of space acquisition policy as defined in National Security Space (NSS) Acquisition Policy 03-01. The real value comes from showing how the specific job of a government acquisition person contributes to the entire program office activity.

Curriculum & Staff

The nine functional areas are contracting, program management, acquisition logistics, information technology, business and finance, safety, quality assurance, systems planning, research development, and engineering (SPRDE), and test & evaluation. The course's repertoire of classes boasts approximately 60 offerings. In addition to giving the students an overall flavor of areas encompassing the business done at SMC, the classes are meticulously geared toward preparing the students for each phase of the acquisition process. The cadre of instructors includes both SAS-staff members and guest instructors who serve as subject matter experts in various areas. SMC has taken a bottom-up (what an individual needs to know to execute their job) and top-down (what the supervisor wants them to know) approach to defining the curriculum. It's not just the specialized instructor cadre, but the instructional system design implemented by the SAS staff, that ensures each space professional meets the required learning objectives.

Local Industry Tours

The SAS has teamed with many industry partners to develop the personal touch to the hands-on experience offered. In addition to Exchange-With-Industry programs already ongoing within the Air Force, SAS offers the students direct access to a broad range of the space industry. Each tour offers an invaluable look into the products, expertise, and processes SMC's industry partners use to design, manufacture, and test space products.

A tour at The Boeing Company gives students the chance to see first-hand how contractors develop and handle the government and commercial satellites with which they will interface over the span of their careers in the space community. The students are introduced to systems such as the Wideband Gapfiller Satellite, an XM Radio satellite, and other international communication satellite projects. These experiences provide insight into the developmental test process through which the satellites must go – which is one of the main cost drivers for any satellite/launch program. One of the visual highlights of the tour is the three thermo-vacuum chambers, one of which is the largest in North America. An essential element of a satellite test program, a thermo-vacuum chamber creates a space-like atmosphere, devoid of air, and when coupled with intense, space-levels of cold, heat and radiation, effectively tests satellites and their components in a simulated space environment.

2nd Lt James Carroll makes a final check on his class' plane before preparing to launch it.

The tour of The Aerospace Corporation's laboratory complex features a look into the different research and developmental methods used to develop and test various new ground-breaking technologies. In addition to a "sneak peak" at emerging advances related to the space and missile business, students are introduced to the local "center" of space technology. Students get more than just tours of The Aerospace Corporation.

The SAS program also exposes the students to the Sea Launch experience. Run by an international consortium, Sea Launch combines proven launch systems with marine-based operations to provide heavy-lift launch services for commercial customers around the globe. Demonstrating the capability to process and transfer payloads from equatorial locations in the Pacific Ocean is probably the most distinct experience that students are exposed to in the Long Beach area. Exposure to alternate launching mechanisms and locations encourages the students in thinking "outside the box." This hands-on approach not only prepares the students for critical thinking but also provides students the motivation and excitement of belonging to the space business.

Off-site Training

Vandenberg AFB, California, and Patrick AFB, Florida – our two premier major range and test facility bases, are where the off-site test & evaluation (T&E) training is held. About two weeks into the course, the students travel up the coast to Vandenberg AFB to experience the Western Launch Range, focusing on range control and range safety. Three weeks later, the students head on a cross-country trek to Patrick AFB, where they are immersed into the T&E of space systems. Numerous reservist-led site visits and classes expose them to the people and facilities involved in launch vehicle preparations, satellite processing, and test procedures. One class was fortunate enough to see a night launch of the Titan IV. Although no class has been lucky enough to see a space shuttle launch in person, students generally felt excited to see the Space Shuttle Discovery on its launch pad and Space Shuttle Atlantis up close in the Orbiter Processing Facility. These experiences not only evoked a feeling of personal involvement, but also invited students to dream of future career possibilities.

Col James R. Horejsi (MS, Low Observables Engineering, Air Force Institute of Technology, Wright Patterson AFB, Ohio) is the Space and Missile Systems Center (SMC) Chief Engineer and Deputy Director, Systems Acquisition Directorate, SMC, Air Force Space Command, Los Angeles Air Force Base, California. Throughout his career, Colonel Horejsi served in every aspect of weapon systems and space acquisition. Beginning his career as a Threat Analyst on key communications satellites (MILSTAR, DSCS, and FLTSACOM), he was then assigned to provide engineering, test, financial, and program management support for a variety of weapons programs. Colonel Horejsi later became Chief Engineer in the Ballistic Missile Office, Norton AFB, California and later went to the Pentagon as a B-2 Program Element Monitor working with Congress, OSD, and Air Staff on low observables, flight test, and financial management. He has been involved in everything from obtaining SECDEF certification of the B-2's stealth performance to transitioning it to operational status. Colonel Horejsi later returned to SMC as the Chief, Air and Space Integration in the Directorate of Developmental Planning where he worked at demonstrating the value of space capabilities via joint experiments, exercises, and war games. Finally, he returned to the Pentagon as Executive Secretary for the Special Programs Review Group where he worked with OSD and Congress to manage the $2.2 billion annual AF special access program portfolio.

Acquisition Process

The "meat and potatoes" of the course is a design lab based on the NSS 03-01 acquisition process. Students first divide into two teams, government and contractor, as they embark on their mission to launch a simulated sensor (aerial reconnaissance) package to a certain altitude, hover for a specified time and then descend to a recovery point. Mr. Jaime Rico, acting Chancellor of the SPTP stated, "We try to address the risk at hand in having only one shot at putting up a satellite. Our goal is to instill critical thinking in the students so they will cover all of the bases needed to ensure mission success – an approach that will benefit them in their future careers." Major Reed, Chief of SAS said, "They get a lot of hands-on experience to understand the process from A-to-Z. The students actually develop and acquire a product and launch it. In a short period of time, they are exposed to the whole acquisition process and the products that must be delivered in sequence to accomplish that process." After the two teams collectively develop NSS 03-01 required documents, conduct four major milestone reviews, and perform developmental testing, the acquisition process culminates with Operational Test & Evaluation (OT&E) of the product the students developed. It is in this final OT&E of their system that the real value of attention to detail early on hits home to the students.

The key to the success of the SAS has been the commitment of SMC's leadership to recognize and accept its responsibility to grow future generations of space acquisition professionals. No one else can do it for us. By exposing the students in a hands-on approach to the reality of just how difficult the space acquisition business can be, they begin to understand why SMC and its industry partners operate the way they do. From the complex rules of acquisition, to the pitfalls inherent in the business, to the difficult act of balancing cost, schedule and performance, the integrative experience of the hands-on design lab is critical to effective learning for the young professional. And finally, the motivational experience of seeing first-hand the satellites and launch vehicles and how they are handled "in the field" puts it all in context. In the end, that's what the SAS is all about. Creating experienced, motivated space acquisition professionals.

Lessons Learned from Space Vehicle Test Trends

Mr. Bruce Arnheim
Director of Mission Assurance & Launch Integration,
Space Based Surveillance Division,
The Aerospace Corporation

Background and Objectives

Space acquisition in the 1990s resulted in significant changes across the industry. The drive to reduce costs and schedules led to increased risk taken on by the US government. This trend resulted in six launch failures between 1998 and 1999 and a number of space vehicle problems. The government sponsored a number of investigative teams to look at the era's trends towards tighter schedules, decreased testing, and generally reduced mission success. Recent studies have confirmed that we must refocus our attention on mission success.

The Aerospace Corporation supports the Space and Missile Systems Center (SMC) to acquire space systems and launch vehicles. In that capacity, Aerospace has performed analysis and research exploring acquisition approaches and lessons learned to compare and identify how we can best achieve mission success. An Aerospace study was commissioned to assess anomaly and test trends in SMC programs. We have compared the findings from our SMC study to data from previous studies of other government space vehicle programs (herein referred to as recent studies) and have identified significant similarities and differences.

The scope of the study was to address trends in primary SMC space assets spanning the last 20 years. We looked at four of the key SMC space missions: navigation (Global Positioning System), surveillance (Defense Support Program, space-based infrared system), weather (Defense Meteorological Satellite Program, National Polar-Orbiting Operational Environmental Satellite System), and communication (Defense Satellite Communications System, military strategic and tactical relay system, Wideband Gapfiller Satellite, Advanced Extremely High Frequency). The idea was to compare anomaly history and test trends to recent studies performed by The Aerospace Corporation looking at other government space assets. The first observation (figure 1) is that the SMC constellations currently being fielded are legacy designs reaching back into the 1980s and earlier. The diamonds in figure 1 indicate first launch for each block. The good news is that current programs under development have not yet been launched and there may remain opportunities to address some issues during the latter part of their development. The challenge is that SMC has not seen this number of simultaneous new acquisitions for over 20 years. The study looked at histories of 76 legacy SMC space vehicles.

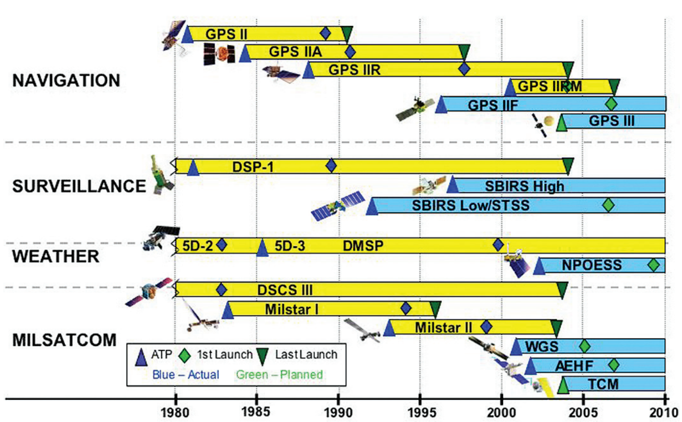


Figure 1. Overview of SMC primary space vehicle programs.

On-Orbit Anomaly Analysis

A flight critical anomaly is an on-orbit anomaly that if undetected, would result in a loss of a specified mission. Recent studies conducted on other government space vehicle programs provided valuable insights into trends of on-orbit anomalies. The recent studies of other government vehicles identified an alarming six-fold increase in flight critical anomalies for post-1995 launched space vehicles. Our study uncovered only three flight critical anomalies out of 71 SMC vehicle histories analyzed. Also, there were no flight critical anomalies identified for more recently launched vehicles. As SMC has not yet launched systems developed after 1995, it is unclear if the six-fold increase in flight critical failures experienced on other systems would be realized with the new SMC systems. Figure

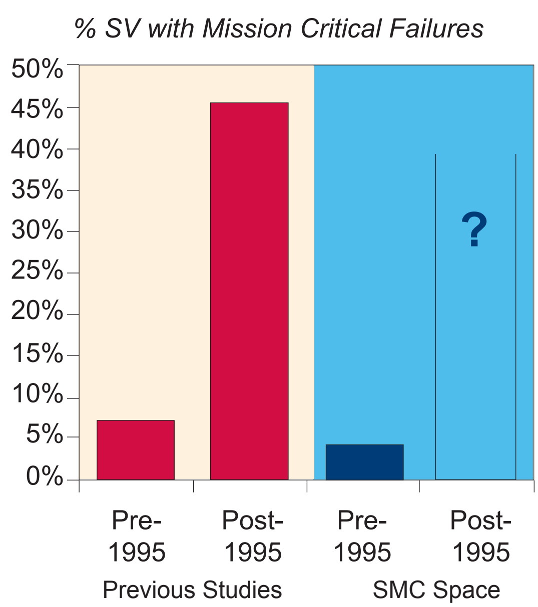


Figure 2. Percent of flight critical anomalies for pre-1995 and post-1995 space systems.

2 shows that pre-1995 SMC flight critical anomaly history is in family with the legacy systems of other government acquisitions and that the increased anomaly trend of post-1995 has not been realized by launched SMC systems.

Our study then reviewed mission degrading anomalies (MDA). A mission degrading anomaly is defined as an anomaly, if undetected and launched, would change the mission reliability or timely delivery of a mission product. For example, if an electronic box fails and a redundant unit was to be used instead, this would be considered a mission degrading anomaly.

Previous studies, identified a dramatic 80 percent increase in mission degrading anomalies per space vehicle for systems launched after 1995. As shown in figure 3, the SMC MDA history shows remarkably comparable results relative to pre-1995 systems analyzed in previous studies.

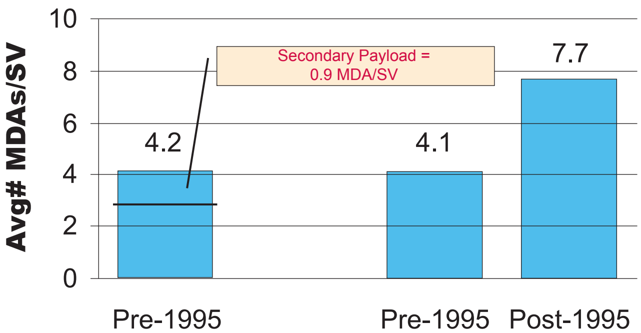


Figure 3. Comparison of Pre- and Post-1995 on-orbit mission degrading anomalies.

We reviewed each anomaly for patterns, root cause and lessons learned. An interesting observation with the SMC anomalies is that a full 25 percent of the anomalies are attributable to the secondary payload. On a piece parts basis, a secondary payload has relatively few piece parts hence, from a reliability standpoint, we would expect to see a comparably fewer number of anomalies. The acquisition approach for secondary payloads at SMC is such that payloads often arrive as government furnished equipment (GFE) from other government organizations which is different than the predominant approach of the other government systems studied. With the SMC approach, the space vehicle System Program Office (SPO) has no direct control over the build of the hardware which may impact the quality of the flown product. Another factor maybe that secondary SMC payloads are more experimental and carry more inherent risk. Regardless, the high percentage of anomalies attributable to secondary payloads suggest that further investigation be pursued and perhaps this acquisition approach be reconsidered.

Another interesting observation of the data occurred on analysis of follow-on block vehicles that are manufactured by the same contractor. The Young Panel observed that in the 1990s, the incumbent contractor was most likely to not win the follow-on contract.[1] As can be seen with this data (figure 4), there is a price to pay with that approach. Beyond the additional non-recurring costs of a new contractor, the data shows that the older contractor does learn from their past experience. In four out of five programs where the incumbent continued with the follow-on vehicle, there was a significant decrease in the number of on-orbit mission degrading anomalies.

MDA Change for Follow-on Vehicles Built by Incumbent	
Program	% Chg
A	-75%
B	-90%
C	-25%
D	-50%
E	25%

Figure 4. Decrease in MDAs when the incumbent builds the follow-on space vehicle.

In four out of five programs where the incumbent continued with the follow-on vehicle, there was a significant decrease in the number of on-orbit mission degrading anomalies.

Factory Test Trends

As operational data are not available for the newer SMC systems, insight into the test programs can be beneficial by looking at the test plans for each of the programs and comparing newer programs to older ones. Test programs were compared for 14 SMC programs and system test anomalies were reviewed and categorized for 22 vehicles. Further insight into test trends was obtained through a review of the primary trends in system test anomaly causes. With that insight (and further investigation), an Environmental Test Thoroughness Index (ETTI) can be computed for each program. The environmental test thoroughness index is a quantifiable metric developed by The Aerospace Corporation that compares an environmental test program to requirements documented in MIL STD 1540B.[2] Research has shown that there is a relationship between ETTI scores with the number of early flight mission degrading anomalies normalized by parts count as a measure of complexity.[3] The relationship shows that increased ETTI, meaning an environmental test program that more closely complies with MIL STD 1540B, tends to experience fewer early on-orbit anomalies.

Review of the test programs at SMC show an average decline of 13 percent in ETTI since 1995. The decline in ETTI was consistent across all SMC mission areas. As shown in figure 5, previous studies of non-SMC programs, show an average 8 percent decline in environmental test thoroughness. SMC has rec-

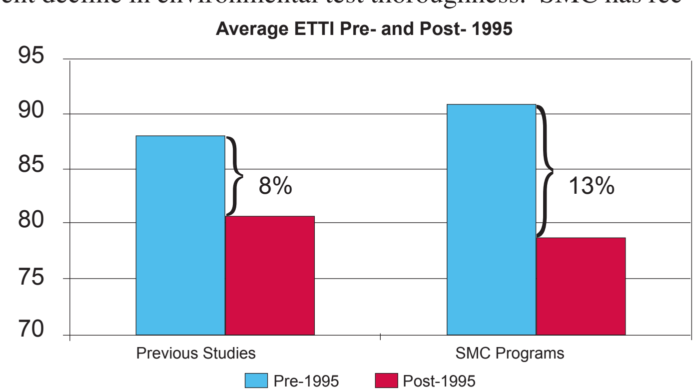


Figure 5. Average ETTI scores for Pre- and Post-1995 space vehicles.

Considerable efforts over the last several years have been applied to reinvigorate SMC development and test programs and refocus on mission success.

ognized that the decline in SMC test thoroughness could result in similar on-orbit anomaly trends in systems to be launched. Considerable efforts over the last several years have been applied to reinvigorate SMC development and test programs and refocus on mission success.

The study also investigated factory test anomaly trends. For an anomaly to be counted in this set, the anomaly had to impact flight hardware or software. No procedural, test equipment, or operator errors were included in this tally. Starting from the right in figure 6, the previous studies showed a decrease in workmanship failures occurring on the post-1995 vehicle set. This was considered encouraging news, as this indicates that test personnel are making fewer mistakes during system test and that processes are being followed. However, the post-1995 SMC data set was considerably above the pre-1995 level.

Another aspect of the SMC acquisition approach is that there is a tendency for production vehicles to remain on the ground for longer periods than other systems. This presents greater "opportunity" for the SPO to change hardware after it is built based on operational experience and parts issues that surface after production. Greater time modifying hardware, however, also presents a greater chance for workmanship errors to occur.

Further analysis showed that acquisition strategy potentially contributed to the higher number of workmanship anomalies. Systems in previous studies tend to build one or two vehicles at a time whereas SMC systems have larger quantity buys. As a result, training and learning curve is a bigger factor for SMC systems. This is what we call the "A team / B team" effect. For new programs, the test team tends to consist of the greatest talent (a.k.a. The "A team"). After the first or second build, the "A team" moves on to the next new program. The "B team" replaces these people, requiring training and opening up the opportunity for increased workmanship errors. This was evidenced by an increased number of workmanship anomalies showing up around the third of a production run and was confirmed by interviews with SPO personnel. Analysis of the data also showed a tendency towards procedural error impacting flight hardware, indicating less adherence to process during later builds.

One startling discovery in previous studies was that recent vehicles had more design defects, uncovered during system level testing. This was attributed, in part, due to an increase in the complexity of the newer systems. That is not the case with the SMC systems. Previous studies have uncovered that newer systems incurred a fundamental breakdown in systems engineering processes and the rigor in which systems engineering was being applied to the newer programs. The high number of design defects encountered in this study suggests that the systems engineering breakdown may have already occurred on SMC systems as evidenced in the higher number of design defects found in pre-1995 SMC systems.

Another observation from this study and previous studies was that a greater number of test requirements were being deferred to higher levels of assembly. That increase in requirements also increases the likelihood that design defects will increase at the system level and potentially on-orbit.

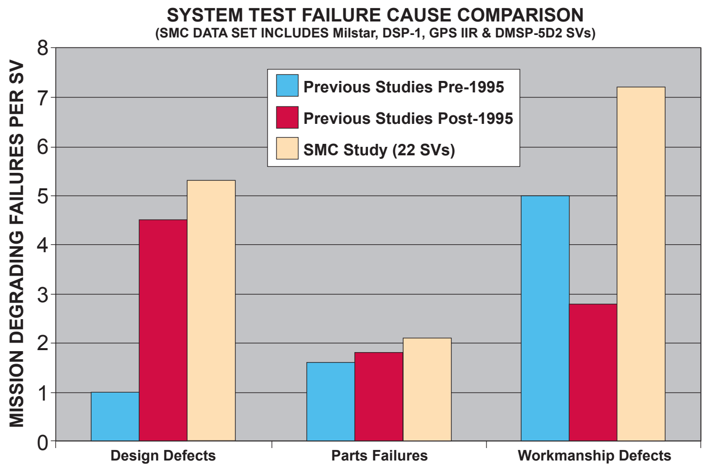


Figure 6. System test anomaly trends.

Some Other Test Observations

It is important to note that the focus of this study was on environmental test. There are other program aspects and trends that should also be addressed to improve mission success. Examples of those aspects needing greater focus include adequate parts screening, improvement in test perceptiveness, and improving test technology as systems improve technologically.

In light of recent parts failures that have been very costly to a number of programs, it was interesting to find that the number of parts failures occurring at system test have remained relatively constant over a broad timeframe and vehicle set. It is very important to note that although the number of parts failures have remained relatively constant, the impact of those parts failures have impacted the industry many-fold. Industry trends show that the parts supplier base has shrunk significantly. Similarly, in an effort to reduce cost, vehicle manufacturers have combined parts procurements over multiple programs. Therefore, instead of the stovepipe acquisition approach yielding a part failure that only impacts one program, a single part failure can now impact multiple programs.

One of the biggest lessons learned missed on recent programs is a divergence away from a test like you fly philosophy. With more complex systems, test like you fly is more critical now than ever before, but due to cost and schedule constraints, less of this is being applied.

One of the biggest lessons learned missed on recent programs is a divergence away from a test like you fly philosophy.

With the increase in complexity of constellations and more systems being assimilated into existing ground infrastructure, there is a tighter coupling between ground and flight software. This leads to a need to put greater emphasis on inter-segment testing and verification of a program's mission threads. Additionally, in the past, programs tended to take the time to repair problems when they occurred then repeat the failed test. With schedule pressures today, programs have a greater tendency to not repeat the failed test, thus assuming greater risk.

As programs are taking on more risk and looking for ways to reduce costs, the industry has shifted from building dedicated qualification hardware and testing it beyond the expected flight conditions. Instead, a protoqualification approach to hardware qualification is being used, which tests only slightly above predicted flight environments but has the cost benefit of saving the manufacture of additional components that would not fly. The drawback is that less flight margin is demonstrated and the process is less rigorous at defect screening. Also, what is not often understood is that program risk is also increased not only due to technical reasons just described, but any problems that occur are more likely to impact the critical path. With only flight hardware being built, there no longer is a parallel development path in the schedule and schedule risk is increased.

Schedule

The SMC study looked at schedule execution in order to identify potential impacts to testing. The focus was on the difference between planned versus actual schedules (slip) over the last three decades. A number of legacy SMC systems were initially developed in the 1970s. The study looked at contractor planned schedules from authority to proceed (ATP) to launch versus actuals. Figure 8 shows that on average, 1970s era space vehicles slipped an average of 89 percent from ATP to launch. Average program slip for pre-1995 SMC acquisitions are comparable to other government space acquisitions coming in at 68 percent. At the risk of stating the obvious, government space acquisitions actual deliveries take considerably longer to launch than originally planned.

Further research was performed into programmatic cost and schedule drivers, however we will save that discussion for another time. Suffice it to say that the reasons for schedule slip vary and are driven by both government and contractor issues and decisions.

By comparison, data on post-1995 program slips on non-SMC programs shows a reduction in schedule slippage for recent programs. Upon further research, the study found that the reduction in schedule was due to a 40 percent reduction in system test time. Thus, schedule pressures have impacted system test schedules. The resultant schedule pressures and potential compromise in quality of testing (among other factors) have potentially led non-SMC programs to a corresponding increase in on-orbit failures.

	70s	Pre-1995	Post-1995
Prev. Studies		62%	36%
SMC Progs.	89%	68%	?

40% reduction in system test time!

Figure 7. Percentage of program schedule slip by era.

Complexity

Studies of non-SMC systems showed significant growth in complexity as represented by weight growth and parts count per vehicle. The goal of this aspect of the SMC study was to identify if parts and weight was growing as much for SMC vehicles as it was for other government space vehicles.

Recent SMC systems showed some growth in piece parts counts however it was not as significant as with other government systems. A look at weight growth yielded similar results. Other systems showed weight growth trend was increasing significantly. Not nearly as significant of an increasing trend was seen with SMC vehicles. Generally, it can be observed that the other systems studied were generally striving to maximize capability whereas the SMC systems strived to fit onto existing launch vehicles, thus constraining piece part count and weight.

Another aspect of space vehicle complexity, which is growing more significantly than hardware, is on-board software as measured here as thousand source lines of code (KSLOC). A survey of flight software lines of code relative to launch year is shown in figure 8. The red trendline shows that newer systems are planning on flying significantly greater software than on traditional systems. Follow-on systems tend to not be growing as fast (blue line).

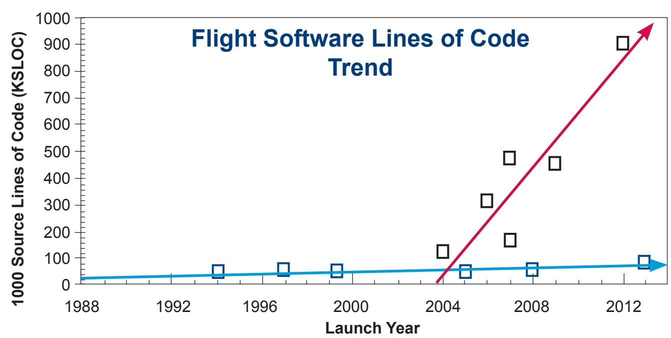


Figure 8. Flight software lines of code trend for SMC space vehicles.

This software growth in flight has a number of implications. The study developed models to predict the expected number of on-orbit anomalies that can be attributed to software. As expected, software related anomalies would follow the increased growth in flight lines of code. With this kind of insight, we can be prepared for the change in our operational future. We can prepare by ensuring sufficient software personnel and simulators are provided to support ground operations to accommodate the exponential increase in expected anomalies.

Also, the increase in anomalies is not pre-destined. Another way to address potential increased anomalies is to improve the quality of software being flown. SMC is working diligently to establish standards and processes that ensure high quality software is delivered on-orbit. To date, experience has shown that the development of quality software is costly and time consuming. Success in this arena is akin to learning how to build quality hardware in the 1960s.

Summary

The Aerospace SMC study showed that the acquisition approach of acquiring more space vehicles per build provides

SMC the opportunity to learn from other systems before the SMC systems are being fielded. In this case, the increased on-orbit failure trend of other systems can be addressed by SMC before launch. SMC, combined with other government systems studied, are showing less diligence in environmental testing, while risk is being deferred to higher levels of assembly. At the same time with other systems, less time is being spent in test, thus potentially deferring anomalies past launch into operations.

The lessons learned from the Aerospace study of SMC space vehicle test trends, are helping to focus national security space initiatives to establish more disciplined systems engineering, verification, and mission-assurance strategies.[4] Specific initiatives at SMC include comprehensive workforce training, reintroduction of selective specs and standards, enhanced parts and component management and improved software acquisition practices. SMC is partnering with industry to address several of the issues identified as watch items in the test study. Along with the National Reconnaissance Office, the Missile Defense Agency and the National Aeronautics and Space Administration, SMC is a sponsor of the Space Quality Improvement Council (SQIC), a forum facilitated by the Aerospace Corporation and consisting of representatives from major US prime and subcontractor organizations. SMC has taken a leadership role to pro-actively address potential risks to space programs that may have resulted from changes in mission assurance due to the evolution of acquisition practices. With this reinvigorated focus on mission success, we hope to provide high quality space systems throughout the 21st century.

Notes:

[1] "Report of the Defense Science Board/Air Force Scientific Advisory Board Joint Task Force on Acquisition of National Security Space Programs," Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, May 2003.

[2] R.B. Laube,"The Environmental Test Thoroughness Index," Aerospace Report Number TOR-0086(6902-06)-2, The Aerospace Corporation, 1986; Department of Defense, Miltary Standard, Test Requirements for Space Vehicles, MIL-STD-1540B (USAF), 10 October 1982.

[3] B.L. Arnheim, W.F. Tosney, and J.B. Clark, "The Influence of Development and Test on Mission Success," 4th International Symposium on Environmental Testing for Space Programmes, June 2001.

[4] The Aerospace Corporation, *Crosslink* 6, no. 3 (Fall 2005).

Bruce Arnheim (Dual BS, Engineering, Harvey Mudd College, Economics, Claremont McKenna College, MBA, Business Administration, Pepperdine University) is the Director of Mission Assurance and Launch Integration in the Space Based Surveillance Division of The Aerospace Corporation, an independent, non-profit organization that acts as scientific and technical advisor to the US Air Force and the Department of Defense on space systems. In his current role, Mr. Arnheim oversees the mission assurance, launch planning, and inter-segment test activities on the Space Based Infrared System program. In his former role as Director of the Cross Program Research Office at Aerospace, Mr. Arnheim was responsible for conducting aerospace industry studies into the fields of lessons learned, test effectiveness, schedule planning and modeling and trade studies. He has served as key technical lead on many red teams and readiness review panels, and has been responsible for leading and performing cross program studies such as the ones identified in this article. For over 27 years, Mr. Arnheim has been involved in space systems engineering and manufacture, first at Hughes Aircraft Company (now Boeing) and now at Aerospace. He was the winner of the Otto Hamberg Best Paper Award for his work in space environmental test, and is the winner of two NRO Director's awards. Mr. Arnheim has been a member of the Aerospace Test Seminar's Advisory Board for over 15 years.

Space Environmental Protection: The Air Force Role

Mr. John R. Edwards
Air Force Space and Missile Systems Center
Dr. William H. Ailor
The Aerospace Corporation

Since the beginning of the space age, space has been viewed as the New Frontier, as vast tracts of wide-open nothingness. A nation or company wanting to launch a satellite could simply pick a time and, assuming ground-based weather permitted, go for it. Sure, there were hazards in the space environment like solar storms and micrometeoroids that could damage sensitive components, but satellites and crewed vehicles could be protected by proper design.

Over the last 40-plus years, a new dimension has been added to the space environment that has the potential to actually destroy or seriously damage an operating satellite—space debris. Space debris—dead satellites, fragments of exploded rocket stages, and even the occasional wrench lost by astronauts—has accumulated in near-Earth space to the point where the probability of an operating satellite being seriously damaged or destroyed by collision with another orbiting object is no longer negligibly small.

Just as years of freely dumping chemicals into vast tracts of ground contaminated our water and made regulation necessary, space close to Earth is becoming contaminated and rules are emerging to protect this essential resource. In 1987, a United Nations (UN) environmental report described space as a limited "global commons" resource, an addition to the atmosphere, hydrosphere, lithosphere, and biosphere that we all share.[1] Recognizing this, space-faring nations have joined together to develop guidelines designed to help minimize the future growth of space debris. The Air Force is an active leader in these efforts.

This article summarizes effects of human activities on the space environment, discusses international efforts to limit future growth of debris, and describes Air Force involvement, policies, and acquisition activities designed to ensure that Air Force space missions comply with emerging guidelines and helps protect this sensitive but critical resource.

Space Debris: More with Time

In the beginning, there was only one major object orbiting our planet—the Moon. When humans began exploring and exploiting this new "high frontier" less than 50 years ago, there was virtually no concern that a rocket or satellite would be hit by anything large enough to completely destroy it (unless a micrometeoroid happened to hit a propellant tank).

In less than half a century thousands of manmade objects have been put into orbit, and they and the debris they have shed or produced have changed the picture substantially.

For years, rocket stages were simply left in orbit after separating from their payloads; explosive metal bands were used to separate payloads from stages; explosive bolts sprayed metal fragments when they fired; lens covers were released and allowed to float away; and satellites were simply abandoned when their missions ended, with no concern about the possibility that pressurized tanks might explode at some future date or that these large objects could themselves be involved in future collisions.

These practices led to a rapid growth in the number of tracked objects in the Air Force's Resident Space Object catalog. The number of tracked objects has also increased due to improved tracking over the years, which reduced the size of the objects that could be tracked. For example, recent radar upgrades added over 3,000 existing but previously untracked objects to the catalog (a "tracked object" is sufficiently known that its orbit has been determined and its future locations can be predicted). Currently, objects 5 cm and larger are tracked. Estimates are that more than 100,000 untracked objects larger than 1 cm but smaller than 5 cm are currently in orbit.

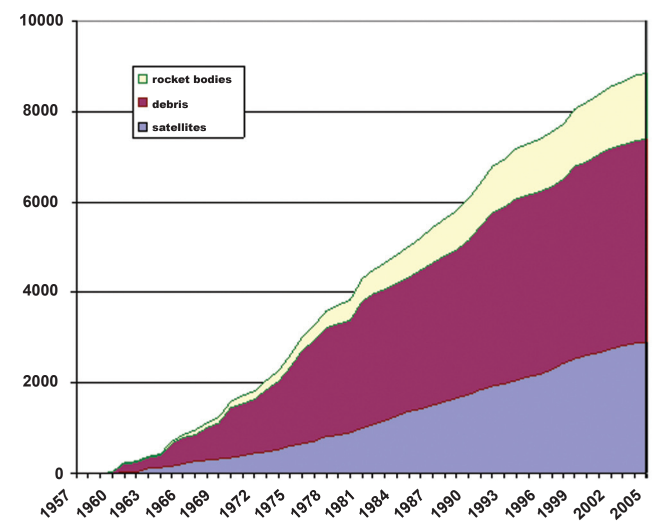
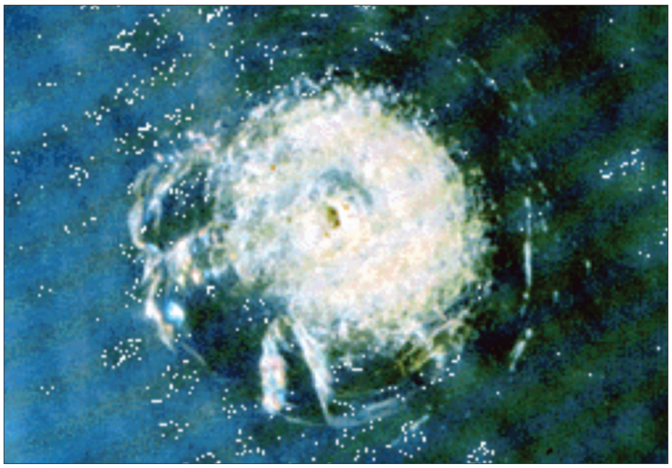


Figure 1. Number of tracked objects in orbit.

The Air Force currently operates more than 140 active satellites.[2] Among these are the 24 Global Positioning System (GPS) satellites, specialized communications satellites, and satellites used for remote sensing, weather, and surveillance. All of these satellites perform missions critical to our national defense; assuring an environment that does not threaten them or their operations is a Department of Defense (DoD) as well as a national priority. For this reason, the Air Force has been active in efforts both to understand the nature of the space debris population and to minimize its growth.

A primary source of space debris has been on-orbit explosions. Since 1960, there have been 88 explosive, debris producing events, yielding over 4,400 new (tracked) orbiting objects and doubtless many more fragments too small to track.[3] Clearly, reducing the possibility of new debris from explosions should be an important part of an overall debris mitigation strategy.

A major reason for concern about space debris is the threat even a tiny fragment poses to the operation of a satellite. For example, a flake of paint can chip a sensitive mirror or optical device, or a small fragment from an exploded stage can seriously damage a much larger satellite if it hits in the wrong place. The reason for this is the very high relative velocities, sometimes exceeding 10 km/sec (22,370 mi/hr), typical of objects in low Earth orbits. While the collision velocity might be less in geosynchronous orbits, collisions are generally bad things for delicate, expensive satellites.



NASA

Figure 2. This 4 mm diameter crater in the windshield of the Space Shuttle Orbiter was caused by a 0.2 mm fleck of white paint with an estimated impact speed of 3 to 6 km/sec.

Fortunately, collisions among larger objects are rare, and there have been only three known collisions: a 1991 collision of a Russian non-functional navigation satellite with debris from a sister spacecraft, a 1996 collision of the Cerise satellite with a fragment from a French launch vehicle, and a 2005 collision of two large debris fragments.[4] The probability of collision for a satellite in geosynchronous orbit (35,786 km) is about 1 in 3,000 over a 10-year period; for a satellite in a low Earth orbit (780 km, for example), the collision probability for the same period is approximately 1 in 600. When information on a close approach is available, satellites have been moved to decrease the collision probability. Unfortunately, good quality information of this type is not generally available to satellite operators.

Emerging Policies and Standards

In the 1980s, it was recognized that the increasing population of space debris had the potential to affect satellite operations by increasing the possibility of damage to sensitive sensors or of mission-ending collisions. In fact, some were projecting the possibility of a "cascading" effect—a collision involving two objects would produce debris that would collide with other objects, creating more debris, and so forth. Eventually, an environment that posed a much higher threat to operational satellites would be the result.

These concerns led to the founding of an organization to coordinate space debris research and to recommend, from a technical perspective, measures that could be taken to minimize the growth of space debris. The Inter-Agency Space Debris Coordination Committee (IADC) fostered dialog among all space-faring nations, and the work coordinated by this group has led to recommendations for debris mitigation measures that are now finding their way into national and international rules and regulations that govern the use of this important resource.[5] The Air Force, with representation by the Space and Missile Systems Center (SMC) and Air Force Space Command (AFSPC), are active members of the National Aeronautics and Space Administration (NASA) delegation to IADC.

The IADC developed recommendations for minimizing the growth of space debris. These recommendations fall into four areas:

- Limit debris released during normal operations,
- Minimize the potential for on-orbit breakups,
- Dispose of hardware at the end of its mission, and
- Prevent on-orbit collisions.

IADC recommendations and general recognition of an emerging orbital debris problem by space-faring nations are encouraging the development of new international standards by the International Organization for Standardization (ISO). ISO's role is to evolve, by international agreement, best practices that support space debris mitigation measures. ISO standards provide details and guidance on how operators and manufacturers can comply with the overall debris mitigation objective. Once ISO standards are established, purchasers of satellites, launch vehicles, and satellite operations services can simply require by contract that providers abide by appropriate ISO standards.

The Air Force has supported involvement by The Aerospace Corporation in the development of ISO standards, many of which have evolved from standards developed previously for Air Force missions. In fact, as will be discussed later, the Air Force has developed and has been using a process for reviewing debris mitigation plans for both on-orbit and new systems for several years. The Air Force also maintains metrics on the overall performance of its programs in achieving mitigation goals, and SMC developed a handbook to assist space programs in identifying and reducing potential debris.[6]

Although early in the process, ISO is working on standards for end-of-mission disposal of satellites operating in geosynchronous orbits, methods for measuring fuel remaining (important for assuring sufficient fuel remains for the disposal maneuver), and techniques for estimating ground hazards from debris from reentering space hardware. An important part of these emerging standards is the Orbital Debris Mitigation Plan, a document that is developed early in a program and evolves as the program matures. The plan would include information on steps taken to prevent release of debris during launch, orbit insertion, and operations and would provide specifics on disposal criteria.

The Air Force Role

As a major buyer and operator of satellites, operator of the world's foremost satellite tracking network and owner of the world's best catalog of tracked objects, the Air Force has an important role in each of the four areas identified by the IADC to minimize growth of space debris.

Limit debris released during normal operations means that spacecraft must be designed not to release debris such as lens covers, debris from separation and deployment systems, and paint flakes from aging systems. Many of these can be prevented by assuring that satellites are manufactured with non-debris-producing systems and materials. The Air Force is helping minimize the growth of space debris by assuring that manufacturers of Air Force satellites include the latest debris mitigation features in their products.

On-orbit breakups can be prevented by assuring that plans are in place to vent propellant and pressurized tanks, to discharge batteries, and to basically leave a spacecraft as an inert mass at end-of-life. Of course, systems critical to successfully completing these functions must be reliable enough to function at end of life, and again the Air Force is helping assure this by providing proper requirements to manufacturers and operators.

Post mission disposal is becoming more common among satellite operators. The goal is to dispose of hardware at end-of-mission by moving it to a "disposal orbit" or actually reentering the hardware. For satellites operating in geosynchronous orbits, disposal orbits are actually higher than the operational orbit by several hundred kilometers, and these orbits are designed to assure that the dead satellite will essentially never be a threat to those operating only a small distance below.

Satellites in low Earth orbits may be disposed of by reentering them into the Earth's atmosphere, where they will be destroyed by aerodynamic heating and loads, by moving to an orbit with a limited lifetime, or by moving them higher to a disposal region.

Disposal by reentry brings in other considerations, such as predicting the hazard to people, property, and the environment from debris that survives reentry. In some cases, the hazard may be such that the satellite should be deorbited on a trajectory designed to assure that debris lands in the ocean. The Russians deorbited the Mir space station into the Pacific Ocean; NASA and the Air Force regularly dispose of larger space hardware into ocean areas.

NASA

Figure 3. This 250-kg propellant tank survived reentry and landed on a farm in Texas in 1997. The tank was part of a Delta 2nd stage used to launch the Air Force's MSX satellite.

The Air Force has a unique role in *preventing on-orbit collisions*. First, the Air Force provides tracking data for the SpaceTrack web site, where satellite operators can get information on tracked objects.[7] While this data is generally not good enough for collision avoidance applications, some satellite operators have used this data to look for coming close approaches and have actually moved satellites when risks were deemed to be too high.

In 2004, Congress authorized the Secretary of Defense to "carry out a pilot program to determine the feasibility and desirability of providing to non-United States Government entities space surveillance data support," including "satellite tracking services."[8] These services, based on better quality data, could include providing commercial and foreign satellite operators with notices of upcoming close approaches by other orbiting objects. Such notices could help prevent a catastrophic collision event that could create large amounts of debris that would be a threat to all operating satellites in the region. At the present time, the Air Force is the only entity that has the necessary data and could provide such a service on the broad scale, although the Europeans are actively working to improve their capabilities in this area.

A service of this type could also assist with other "environmental" threats to satellite operations. For example, radio frequency interference (RFI) is a growing concern for operators, particularly those operating the communications satellites that bring us television and other services from around the world. RFI events occur when two satellites using the same or similar broadcast frequencies pass in such a way that their transmissions overlap. These events can cause the transmission to be interrupted or decreased in quality. The same tools used to predict satellite close approaches can predict pending RFI events, providing a heads-up to operators and potentially preventing a costly, unexpected interruption.

A major benefit of such a service would be the requirement that all operators provide information on planned maneuvers. Since radars only see where a satellite is now, look-ahead data is essential for meaningful predictions of close approaches, RFI events, and the like. Similarly, if predictions indicate that a maneuver must be performed, simulations must verify that the planned risk reduction maneuver does not create another close approach or interference situation within the prediction window.

This service would, by necessity, bring order to what some might say is a chaotic situation, where operators who want to be good citizens do not know that they might be moving close to another satellite, or know who to call if they are aware of an upcoming problem.

Acquisition Actions - Leadership Directions

The need for organizational support for debris issues was recognized at SMC and a Space Debris Working Group was established under the SMC Environmental Protection Committee (EPC). This organization reports directly to the SMC Vice Commander and includes the primary stakeholders of the debris community, including Development & Transformation Directorate, Safety and the Environmental Management Organizations, Systems Program Offices (SPOs), and The Aerospace Corporation, technical advisor to Air Force launch and satellite programs.

The SMC Space Debris Working Group (SDWG) was established in 1999 under the leadership of then Vice Commander Brigadier General Michael Hamel as the EPC Chairman. Technical support to the EPC is provided by The Aerospace Corporation. Under the subsequent leadership of Vice Commander and EPC Chairman Brigadier General William M. Wilson, Jr., debris metrics were developed and approved in order to provide a baseline assessment of the SMC contribution to the debris environment and also show how well SPOs are complying with development of debris mitigation plans. The tracking helped drive positive behavior and currently all applicable SMC programs have debris mitigation plans in place.

General Wilson also directed that SMC develop processes for handling emergencies related to reentered debris. Policy recommendations and Air Force Instruction wording were made to AFSPC for reentered debris recovery similar to those used for aircraft recovery, so that if reentry debris impacts a public entity, the closest Air Force base would respond, with technical support from the SMC SDWG. Processes were also devised to recover space debris that lands in other countries. In the past eight years, SMC has recovered for analysis five items of reentered debris from locations as far away as Saudi Arabia and Argentina.

While the risk that a reentering object will strike an individual, a structure, or an animal is generally very low, it is not zero. In cases where the predicted risk of human injury or death for a particular reentry event is greater than one in 10,000, policy calls for the reentering object to be intentionally deorbited into a safe area. As noted, the Air Force regularly deorbits larger satellites, but as the picture of the Delta propellant tank given earlier shows, large, hazardous objects related to Air Force programs regularly survive reentry and impact. Fortunately, there are no known injuries or deaths from reentering debris since the advent of the space age (one woman in the Midwest was brushed on the shoulder by a very lightweight piece of reentry debris, but was not injured).

Currently, reentry breakup models are used to predict the hazard posed by the random reentry of a spacecraft. In general, there is very little data available to calibrate these models, and a model that over predicts the hazard could lead to deorbiting a satellite that has mission life remaining.

SMC leads a three-part effort to improve estimation of the hazard posed by reentering objects. The first part involves a trajectory reconstruction and materials analysis of reentered debris to develop data on what actually happened to an object during reentry. For example, debris from the *Columbia* accident was examined to develop response characteristics for composite materials. The Delta 2nd Stage tank was also examined (results indicate that burning aluminum may play a previously unknown but important role in reentry breakup) as shown in figure 3.

Secondly, SMC supports a joint program with NASA and The Aerospace Corporation to develop and fly small sensors on spacecraft and launch vehicle stages to record and transmit data about how the object breaks up as it reenters the atmosphere. This *in situ* data will be unique and will provide a new understanding of the breakup process.

Third, results from measurements and materials analyses are published in the open literature and incorporated into reentry breakup models, leading to more accurate risk predictions. This process may also lead to development of breakup-enhancing features to help assure that hazardous hardware does not survive reentry.

Space Debris Handbook

SMC is focusing on reducing space debris production from the beginning of a program—during the start of the acquisition process. In 2002, an SMC *Orbital/Suborbital Hazards and Debris Mitigation User's Handbook* was produced to acquaint SMC space system developers with various types of space hazards as well as current debris mitigation requirements and best practices developed by SMC space programs. The Aerospace team that developed the handbook was led by Ms. Frankie Shelton, who is the current IADC representative from SMC.

The handbook provides policies and guidelines, discusses debris hazards associated with orbit operations and tests, assists programs in hazard identification, analysis and risk assessment, and monitoring and tracking hazard controls, and identifies program office analysis responsibilities. The document also provides mitigation guidance, discusses orbital stability considerations for disposal orbits, and gives detailed information about design and operational steps to minimize risk and avoid collisions with tracked objects during launch. Hazards from meteoroids and reentering objects are also discussed. An example orbital reentry debris risk analysis for a Delta II Stage 2 is provided to guide programs in reentry heating and casualty expectation calculations.

SMC Debris Mitigation

SMC has ongoing activities and requirements imposed during the acquisition phase for space hardware that help insure the hardware meets debris mitigation policies. These include input to request for proposals (RFP), review of RFPs, input to Acquisition Strategy Plans (ASP), operational safety & suitability evaluation debris clauses, and input to flight worthiness criteria.

The SDWG provides RFP language for specific programs, and standard clauses are in development. SDWG members review all RFPs for conformance with debris requirements, and the SDWG is developing a Contract Delivery Requirements List for debris issues that can be used on future RFPs. Also, as mentioned above, when relevant ISO standards become available, they will be referenced in contracts.

The need for disciplined processes is being met by the leadership of Col James Horejsi, Chief Engineer and former EPC Chairman, who is driving SMC to document key processes. SMC Environmental Management, like the rest of SMC, is developing written operating instructions, and will develop one for debris mitigation. Also, debris questions are being integrated into the Environmental, Safety and Occupational Health Programmatic Risk Tool being developed by Aeronautical Systems Center and SMC to help implement the Environmental Management System required by Executive Order 13148.[9] Another planned action is to develop a standard ASP template for debris that SPOs can use to track items needed for debris mitigation on each program.

A process was also developed to allow certain exceptions from debris mitigation guidelines if changes are not reasonably feasible due to costs or other considerations. For example, it may be unreasonably expensive to modify satellites designed and built before policies were in place. The justification criteria packages include background, current space debris mitigation criteria and plans, alternative solutions, probabilistic risk assessments, and future efforts to comply with guidelines.

The numbers of waivers that have been approved are small: one in 2001, three in 2002, none in 2003, two in 2004, and so far none in 2005. The objective is to make sure that in the future all programs do comply with mitigations guidelines.

SMC also maintains a space debris web page that provides extensive information to users on space debris mitigation requirements and methods.[10] It includes announcements, debris reports, guidance and regulations, and links to other sites. It is available 24/7.

Metrics

SMC maintains metrics for debris mitigation that include both process and performance. On the process side, there are metrics indicating how programs are doing at planning and implementing mitigation. For example, the sample metric below indicates that the Program Office for Program A has prepared and is implementing debris mitigation plans for successive satellite designs. The metric also indicates how many satellites were properly disposed and how many are left to be disposed within each successive "block buy" of several identical satellites.

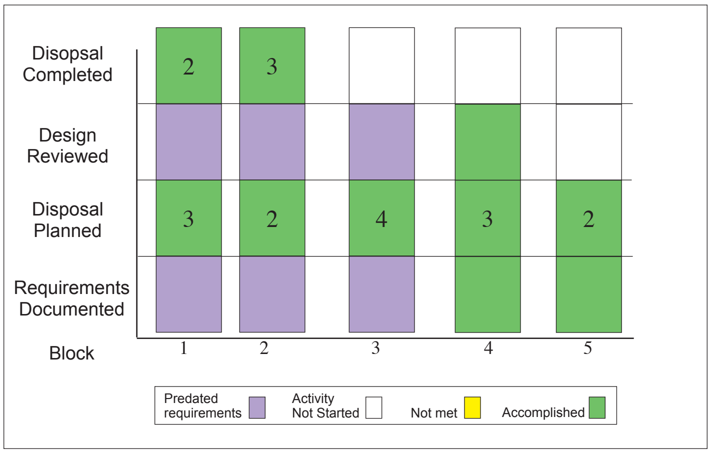


Figure 4. Debris metric developed for EPC under direction of BGen Wilson. Debris Mitigation Metric for Program A.

Performance metrics indicate the compliance of hypothetical vehicles with mitigation guidelines, such as reentering low Earth orbit objects within 25 years after end of operational life or moving to a storage orbit. We expect that as newer systems designed with mitigation are developed, compliance with objectives will improve. Other metrics indicate how much debris is generated by programs relative to other programs and also how much is generated on a per launch and per space vehicle basis.

Environmental Impact Analysis

All government programs with potential to impact the environment must complete a National Environmental Policy Act (NEPA) analysis before implementing the program. Questions about potential impact can arise from the public, from government agencies such as the Environmental Protection Agency or Fish and Wildlife Service, and from the scientific community. For example, in the scientific literature it was observed that in one decade stratospheric aerosols increased tenfold, and the author speculated that it could have been caused by reentering debris that burns up in the upper atmosphere.

To address this question, a study was conducted by TRW for SMC to look at the cumulative impacts from reentering debris

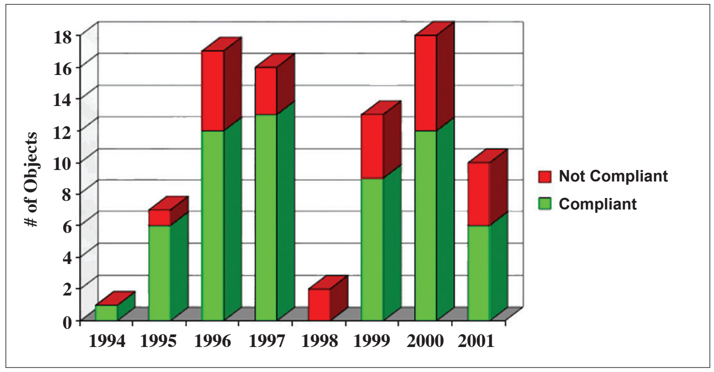


Figure 5. Notional compliance by launch year with orbital debris mitigation guidelines on reentering within 25 years after EOL or moving to storage orbit.

on the atmosphere. In the study, the possible buildup of aluminum oxide in the stratosphere from erosion of reentry debris and the resulting potential for ozone depletion was assessed, as well as the generation of nitrogen oxides (NOx). The study found that the contribution to ozone depletion from this source was extremely low.[11]

Some years ago there was a draft Executive Order (EO) which addressed space itself as part of the human environment, since people fly through it. This would have made NEPA apply to space. SMC made comments to the EO, but it was not issued. However, if such policy ever resurfaces, SMC already has the expertise and knowledge of our systems to address environmental impacts in space.

Reentry debris has been analyzed in SMC NEPA documents since 1993. For example, reentry debris analyses occur in Environmental Assessments (EA) for satellite programs such as STEP Missions 1, 2, and 3, in GPS Block IIR, DSCS, SBIRS, P91-1 and Advanced EHF. Debris has also been analyzed in EAs for other programs such as the Minuteman III and the current Orbital Suborbital Program. During the NEPA process multidisciplinary teams assess potential risk to the public and the environment from reentry debris. Reentering debris may pose potential risk to animals, if they are struck, but also from sonic booms generated by the debris. SMC and Aerospace Corporation debris expertise are on the leading-edge of environmental impact from space programs. With that expertise, SMC and Aerospace Corporation are also helping other agencies such as Missile Defense Agency (MDA) programs complete their environmental analyses, the latest of which is for the Near Field Infra Red Experiment (NFIRE) program.

The Future

The Air Force has been and will continue to be proactive in its efforts to limit the growth of space debris generated by its own space systems, and to understand and limit the hazard posed by reentries of Air Force-related space hardware. SMC is steadily putting processes in place during the acquisition phase that will maximize success in debris reduction in future space systems. The Space Debris Working Group will continue to provide a forum where SPOs, planners, and debris experts can discuss debris aspects of future space architecture and raise issues early to make future programs more sensitive to debris reduction.

Recovery and analysis of reentered debris is helping to understand the reentry breakup process, leading to better models for predicting reentry hazards, and possibly leading to satellite design features that encourage breakup and minimize hazards. Hence, analysis of reentered debris will be a continuing priority, as will the joint program with NASA and The Aerospace Corporation to gather *in situ* data during reentry using onboard, survivable sensors.

The Air Force also has the potential to be a major player in organizing and advising other operators to avoid possible debris-producing collisions of orbiting objects. It may well be that collision avoidance will be a fact of life for future space operations, and the Air Force has the assets and capabilities to maintain a prominent role in this area.

Notes:

[1] *Our Common Future: Report of the World Commission on Environment and Development,* UN, Oxford University Press, 1987.

[2] Schriever AFB, 50th SW, March 2005, http://www.schriever.af.mil/Welcome.aspx?Id=7 (accessed 20 November 2005)

[3] *History of On-Orbit Satellite Fragmentations,* 13th Edition, NASA, May 2004.

[4] NASA Orbital Debris Program Office, SpaceRef.com, status report, http://www.spaceref.com/news/viewsr.html?pid=16201

[5] US Government Orbital Debris Standard Practices, *Orbital Debris Notice,* 17 FCC Rcd at 5590; Department of Defense Instruction, Number 3100.12, 14 September 2000; "Second Report and Order In the Matter of Orbital Debris," Federal Communications Commission, FCC 04-130, 21 June 2004.

[6] *SMC Orbital/Suborbital Hazards and Debris Mitigation User's Handbook,* 2002.

[7] Space Track, www.space-track.org (accessed 20 November 2005).

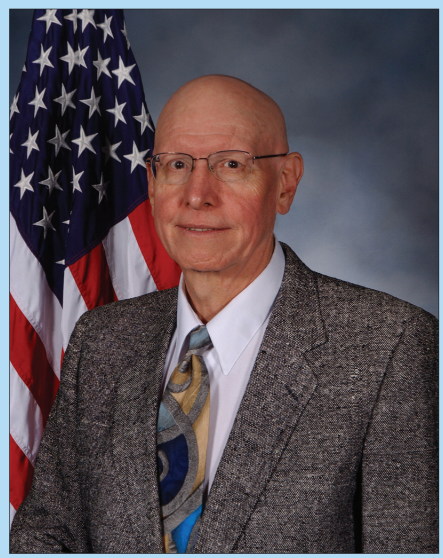
[8] 2004 Defense Authorization Act, Section 913, http://www.defenselink.mil/dodgc/lrs/docs/PL108-136.pdf

[9] "Greening the Government Through Leadership in Environmental Management," Federal Register 65, no. 81 (26 April 2000).

[10] SMC, http://ax.losangeles.af.mil/axf/orbdebris/debris.htm

[11] P. D. Lohn, E. Y. Wong, and M. J. Molina, "The Impact of Deorbiting Space Debris on Stratospheric Ozone," TRW Report, May 1994, http://ax.losangeles.af.mil/axf/studies/docs/idsdso.pdf (accessed 20 November 2005)

Dr. William Ailor (Ph.D., Aerospace Engineering, Purdue University) joined The Aerospace Corporation in 1974. He spent 15 years conducting analyses on spacecraft reentry and reentry breakup and received a NASA Group Achievement Award in 1992 for his work helping to understand the reentry breakup characteristics of the Space Shuttle External Tank. He was chair of the Reentry Subpanel of the Interagency Nuclear Safety Review Panel (INSRP) for the Galileo, Ulysses, Cassini, and Mars Explorer missions (INSRP provides independent assessments to the White House on the safety of space missions containing radioactive materials) and was Reentry Subject Matter Expert for the Mars Exploration Rover and Pluto New Horizons missions. He has appeared on CNN, the Discovery Channel, and the Learning Channel as an expert on reentry breakup and space debris.



John Edwards (MS, Environmental Engineering, USC) is Space and Missile Systems Center's (SMC) Chief, Acquisition Civil & Environmental Engineer. He spent several years analyzing potential environmental impacts from the Air Force version of the Space Shuttle and designed the industry award-winning hazardous waste systems for that program. His environmental analyses for the Saipan Radar, produced a mitigation sign for endangered species featured in a *Lonely Planet* Micronesia travel book. He established SMC's Space Debris Working Group and led the Space Launch Ozone Depleting Chemical Characterization and Reduction Program. Mr. Edwards has won the White House Closing the Circle Award for Environmental Innovation, the Air Force Association Award of Excellence and the AFMC International Award in Armaments Cooperation Team Category.

Restoring Credibility: The Road to Space Acquisition Recovery

Mr. Kurt M. Neuman
HQ AFSPC/XPXS
Northrop Grumman - TASC

We are a Nation at war … a war against an unconventional enemy that is fleeting, elusive, and many times indistinguishable from non-combatants. The very nature of this adversary is challenging the way we plan, acquire, and employ military capabilities. Long-standing warfighting strategies centered on mass, deterrence, and dissuasion are being recast in terms of speed, agility, intelligence, and rapid decision making. Military leaders are emphasizing this will be a war of long duration requiring a new set of resourcefulness and organizational agility.[1] General T. Michael Moseley, Chief of Staff of the Air Force, elaborated, "This country is at war, and we are at war with a very adaptive, very lethal opponent. It is my sense that we will be in a global war on terrorism, for our lifetime."[2] Our ability as a Nation to adapt, rapidly field new capabilities, and shape the environment will be as important to winning the Global War on Terrorism as the ability to employ force when, and if, the adversary is uncovered.

This capacity to swiftly field new capability must apply to our space systems as well as terrestrial programs. Space provides an indispensable advantage in the war on terror. No other medium can provide the global perspective and ubiquitous presence needed to combat such an elusive opponent. However, our ability to meet rapidly changing requirements is being challenged by a new enemy—our own ability to effectively develop and field space systems. In a recent symposium on space acquisition, United States Senator Wayne Allard (R-CO) summed it up succinctly: "Our nation's dominance in space is being challenged not so much from outside this country as from within. In many respects, we have become our own worst enemy."[3]

The situation is serious enough that Congress feels compelled to intervene. Every current major space acquisition program has missed a significant cost, schedule or performance milestone in some way or another. This across-the-board level of unsatisfactory performance has contributed to a credibility crisis within Congress, who is exercising the primary tool available to them to shape acquisition processes—they take money away. This creates a cyclical vacuum as program managers scramble to buy down risk, but find they can only afford to fund minimum technology investments and are forced to restructure programs. Congress recognizes this dilemma but remains skeptical of the space community's ability to deliver results. In the fiscal year 2006 Authorization Bill, Congress directed the Air Force to report on how to improve the space acquisition process and "re-establish the proud legacy of successful satellite development and fielding."[4] This report is due in January 2006.

The problems facing national security space acquisition processes have been widely recognized and well documented.[5] The question remains of how we go about "re-establishing our proud legacy" and meeting the challenges of an unconventional adversary in an irregular war.

The Legacy

Our early space programs are often equated with a spirit of discovery. Adventurous pioneers challenged the bonds of Earth's gravity in our civil space programs while military scientists and engineers took on the daunting task of meeting the threat posed by the former Soviet Union. Our space programs were driven by national imperative—the very need to preserve our existence as a nation was at stake. It became essential to establish the United States as the dominant actor on the international stage and be the first nation to conquer the distance to the Moon.

Today there is not a similar compelling national imperative for space. It could be argued that we are in a war against an adversary who has publicly declared their intent to destroy our way of life; however, that threat, combined with the long-term nature of this war, has not generated the widespread public anxiety experienced when facing down the Soviet Union's nuclear arsenal. The imperatives of the Cold War era not only drove the need for innovation in our early space programs, but it also drove an acceptance of risk, safety breaches, and low environmental standards that would hardly seem appropriate in today's world.

Early space programs combined technology development and acquisition in a trial-and-error approach. Risk-taking was accepted, even at times encouraged, in an all-out effort to ensure national security. The Corona satellite program initiated in the late 1950s suffered twelve straight failures before a successful mission.[6] It is difficult to imagine public tolerance of such a program today given our current safety, environmental, and fiscal responsibilities to the nation's public. While "re-establishing our proud legacy" remains a laudable goal, it needs to be done in the context of today's environment.

The Road to Recovery

We may not be able to compel our Nation to a sense of urgency like the one driven by Cold War politics, but we must be able to foster a spirit of innovation and ability to deliver national security space capabilities to meet the challenges ahead. Given that the road to recovery may be generational in time span, it is essential to begin now to shape our future. It is important to note that space professional development and nurturing systems engineering expertise is fundamental to any advances in space acquisition. While that is a complex subject beyond the scope of this article, we can consider a three part approach to recovery and restoration of credibility. First, we must establish realistic expectations in an effort to "transform transformation" and deliver what is needed, when it is needed. Next, our focus must be on moving technology development out of our acquisition programs and back into the science and technology (S&T) environment so that we "put the risk back into S&T." Finally, we must take steps to restore the health of our industrial base and brace ourselves to "pay more now, expect less later" as we develop conservative, credible cost estimates, and reign in the requirements demands on acquisition programs.

Transforming Transformation

The Department of Defense (DoD) is pursuing two broad avenues of transformation.[7] One path leads to developing overmatch capabilities—those that provide for overwhelming dominance of an adversary. This can be thought of as "Capability Transformation." Examples of programs in this category are the Navy's DD-X destroyer and Air Force's F/A-22. For space, development of Space Radar and the Transformational Satellite Communications System (TSAT) are examples of programs pursuing leap-ahead technologies that will provide dominant advantage in warfighting operations.

The second type of transformation deals with reshaping our Cold War force structure to meet the new world threat. We can call this "Threat Transformation." This transformation takes us out of the traditional warfare box and addresses the challenges of terrorism, ballistic and cruise missile threats, information warfare, and protecting the homeland. It considers responses to disruptive threats that could be devastating to finance, communication, transportation, and public health networks.[8] While considerable policy and planning work has been done in this area, there has not been concerted focus on space solutions to meet non-traditional, disruptive, irregular, or catastrophic threats. Our primary emphasis remains on creating conditions for overmatch capabilities in an effort to develop unrivaled joint warfare effectiveness.

> *"The future holds some big challenges; every system we have is looking for recapitalization right now."*
>
> - Brig General Robert M. Worley II,
> Director of Plans and Programs, HQ AFSPC

It is easy to see why Capability Transformation is favored—every warfighter would prefer to carry a huge advantage into conflict and assure victory through power. However, this type of transformation is difficult to achieve in the absence of a compelling national imperative. Since many warfighting systems depend on current capabilities provided by space, we cannot afford to gap any capability while leap-ahead technologies are pursued. This creates a programmatic "wing walker effect," or the need to maintain a firm grasp on an old technology until the new one is solidly in place. Given the current fiscal environment, there is pressure to adopt acquisition strategies that slow the infusion of new technology through spiral development rather than jumping directly to a new generation of capability.

In order to re-establish credibility in our space acquisition programs, we need to re-examine our approach to Capability Transformation. Risk needs to be pulled out of the acquisition phase and pushed back into S&T programs where technology maturation can occur. Pursuit of leap-ahead capabilities will need to accommodate risk reduction and technology maturation, most likely through spiral development and evolutionary progress. Recognizing that instant advances are unlikely and establishing reasonable expectations will go a long way toward easing credibility problems with Congress, industry, and others.

Space also needs a rigorous examination of Threat Transformation—meeting irregular, disruptive, and catastrophic challenges. Space capabilities remain largely unprotected and highly vulnerable. Furthermore, new space solutions are not being aggressively developed to meet unconventional threats. We have not yet fully pursued space-based capabilities for tagging, tracking, and locating terrorists or terrorist cells and identifying or locating improvised explosive devices. These are the problems that keep our leaders awake at night. A space program that offered a solution—delivered on time and on budget—would truly be transformational.

It is time to take a critical, hard-nosed examination of what we are trying to deliver from our space programs. Given the realities of the fiscal environment, can we really afford to continue development of overmatch capabilities while our space systems remain vulnerable? Should acquisition focus remain on Capability Transformation, or the rapid development of capabilities that are designed to meet the challenges of an irregular threat? In either case, we must establish clear standards and carefully manage expectations. If we are pursuing high risk, leap-ahead technology with enormous potential payoff, we should articulate that strategy but let it be known that capability will be fielded in an incremental fashion on an evolutionary path. If our goal is to more immediately address irregular challenges, we must be careful not to promise more than we can deliver.

Put the Risk Back into Science and Technology

The General Accounting Office (GAO) recently reported that 80 percent of research and development funding was being allocated to acquisition programs while 20 percent was directed to science and technology organizations. The S&T money gets further dispersed across a multitude of programs, while the funds directed to weapons systems remains focused on relatively few programs. This dilution of funding provides incentive for program managers to fund technology development within their program, rather than pushing it to an S&T agency.[9]

The migration of funding away from an S&T environment has considerable repercussions. Since technology development is inherently uncertain, risk is moved from S&T into acquisition programs and often leads to schedule delays and cost overruns. The problem is further complicated by lack of management reserve that would provide flexibility in meeting unexpected costs. Without this flexibility, program mangers are forced to make cuts and work-arounds that often manifest themselves in serious problems once integration testing begins. While Congress expressed limited support for management reserve, they will not institute such a program until space acquisition programs have some proven success—thus reinforcing the need to break the cycle.

Space acquisition programs carry unique challenges that other programs do not face. The operational environment consists of extreme temperature variations and harsh radiation exposure. Primarily due to high launch costs, it is prohibitively expensive to field prototype demonstrations, so we rely on paper-copy design proposals to make source selection decisions. Once hardware is fielded in space, it is typically not feasible to bring it back for improvement or new technology insertion. Software changes may be made, but the hardware design philosophy is that it must work right the first time, every time. One human error can cause a space mission failure that has significant national security implications.[10] In this acquisition environment, technology maturity is essential for success but often difficult to achieve.

The GAO recommended that space acquisition efforts achieve a technology readiness level (TRL) of seven or "system prototype demonstration in an operational environment" before proceeding to the product development phase.[11] For the reasons stated above, this is usually a challenging proposal and many advocate a more conservative goal of TRL 5/6, which requires component validation or prototype demonstration in a "relevant environment." While National Security Space Acquisition Policy 03-01 does not specify a specific TRL requirement, it does state that the Milestone Decision Authority should be informed on key component technology maturity and that "where feasible, critical technology should complete testing in a relevant environment during Phase B."[12] This is consistent with a TRL level of 5/6, without specifying the more stringent requirement of testing in an operational environment.

Several forums have been established to bring technology to a maturity level appropriate for acquisition development and provide consistency across national security space programs. As a result of the 2004 DoD Space S&T Strategy, the Director of Defense Research and Engineering (DDR&E) and the DoD Executive Agent for Space now co-chair a semi-annual Space S&T Summit. This group issued short and long term S&T goals within six strategic focus areas and four broad based operational vectors. Air Force Space Command (AFSPC) also established a structured corporate process to provide S&T guidance and oversight. A recent milestone was achieved when AFSPC issued its first-ever detailed S&T guidance document to assist Air Force Research Lab in its FY 08 program objective memorandum (POM) build. Efforts such as these should go a long way toward providing a basis for funding stability and reducing variations caused by changing user priorities.

The objective of moving technology development out of the acquisition phase and into S&T should be to foster an environment of calculated risk taking. In the S&T arena, failures are often perceived as learning opportunities, similar to the experience of early space programs. Pursuing new discoveries and spending time to acquire knowledge are considered normal, while they are often perceived as detrimental in an acquisition phase.

However, this approach is not without its own set of programmatic risks. In many cases it is easier to slash S&T funding than to cut a major acquisition program, as there is often not an obvious or immediate impact associated with S&T reductions. This year alone, DoD is facing up to a 21.3 percent cut in the S&T budget, down to $10.7 billion. This equates to 2.54 percent of the DoD budget, far short of the Pentagon-endorsed target of 3 percent and the 3.39 percent ratio that was appropriated by Congress in 2005.[13] When budgets are lean it is common to mortgage our future to pay for today. Forums such as the Space S&T Summit and Space S&T Corporate Process must provide an avenue for funding stability and use processes in place to track and report deficiencies in space S&T funding.

Pay More Now, Expect Less Later

Hardly an economic strategy you might use to buy a new car, but "pay more now, expect less later" may be the strategy needed to return our space acquisitions to prosperity. Developing conservative, credible budget estimates and keeping tight control over program requirements are two essential steps in restoring acquisition credibility.

Due to widespread consolidation in the aerospace industry over the last several years, there are a small number of viable companies competing for large contracts that may span ten years or more. To ensure they remain competitive in this market environment, industry teams are submitting bids that typically only have a 20 percent chance of meeting the original program baseline.[14] Combined with the uncertainty of technology development, this often leads to actual costs that are vastly over projected budgets and schedules that are drawn out in order to pay current bills. In cases such as Space Based Infrared System (SBIRS), this has proven to be as much as two and a half times the original cost estimate and six years behind delivery schedule.[15]

It is important to note that many programs such as SBIRS originally develop higher projected budgets than what is put under contract. The government, in an effort to be vigilant over excessive costs and aware that big ticket programs are under scrutiny to be cut, has urged contractors to trim programs and deliver results for less money. This approach, putting cost ahead of mission success, has had significant unintended consequences. The Young Panel recommended that space programs be budgeted to a most probable (80/20) cost, including a reserve of 20-25 percent.[16] This will undoubtedly create some serious "sticker shock" initially, but in the long-term will help prevent unplanned cost increases that have a detrimental impact on future portfolio investment. For example, DoD originally planned to complete expenditures for SBIRS-High in fiscal year 2006. Due to cost increases and schedule delays, it currently plans to spend about $3.4 billion in fiscal years 2007 through 2013.[17] This creates additional pressure across the entire space portfolio and delays anticipated new starts. Accepting that we need to pay more up front and develop conservative budget estimates may be a hard pill to swallow, but it will allow better long term portfolio management and restore credibility in promises to deliver programs as planned.

While we must remain open to realistic budget projections, we must also reign in escalating requirements and "expect less later" after program baselines are established. Users of space capabilities have a nearly insatiable demand and have levied ever increasing requirements on space programs.[18] Long acquisition schedules and high launch costs make this problem even more pervasive. Shortening program timelines may provide some resistance to "requirements creep," but it is clear that a greater level of discipline needs to be added to the requirements process. Program managers need to be empowered to control requirements within the approved baseline. As part of the System Requirements Review and National Security Space Acquisition Policy (NSS) 03-01 process, requirements should be documented and made part of the key space acquisition documentation approved by the Milestone Decision Authority (MDA). Significant changes should require the approval of the MDA prior to key decision points. The Young Panel found that the "Urgent and Compelling" requirements process (first implemented for SBIRS-High) was particularly effective and recommended expanding it to other NSS programs.[19]

Open communication should occur between the requirements and acquisition communities on what is needed and what is deliverable, so that unreasonable expectations do not develop. Separating the "must-haves" from the "nice to haves" is a difficult, but mandatory, step in the road to recovery and restoring credibility in our ability to deliver systems. Processes such as the Joint Capability Integration and Development System (JCIDS) and the Air Force Capabilities Review and Risk Assessment (CRRA) are in place to develop and refine requirements, but better integration needs to occur between these processes and the acquisition system. Reasonable steps to control requirements creep and to expect less later will put us well on the way to acquisition recovery.

"We are where we are…"

The symptoms we are currently experiencing in our space acquisition processes are the result of an illness that started quite some time ago. We need to acknowledge that "we are where we are" and implement steps to move ahead without assessing blame. The road to recovery is a long term endeavor; however, we have made some advances. The one year review of the Young Panel Report noted that we had made great progress in instilling a sense of mission success, but that further work was needed to budget to the most probable cost with a realistic reserve.[20]

We must continue to focus on creating an adaptive, flexible space acquisition system designed to field capabilities that keep us one step ahead of an agile opponent. We should take a critical examination of the emphasis placed on Capability Transformation, especially if it is at the expense of delivering results in Threat Transformation. Careful attention must be paid to moving technology development risk out of acquisition programs and back into the S&T environment, while preserving a stable level of funding. Conservative, achievable budgets must be developed while we keep diligent watch on escalating requirements. All of this is much easier to say than to actually do; however, we must ensure that Senator Allard's warning does not come true. We know who the enemy is, and it is not us.

Kurt M. Neuman (BS, University of Minnesota; MBA, University of New Mexico) is CAAS-ETA support to the Strategy, Doctrine and Policy Branch, Directorate of Plans and Programs, Headquarters Air Force Space Command, Peterson AFB, Colorado. In this capacity he is responsible for analysis of national, military and space strategy, doctrine, and policy to support development of the Air Force Space Command Strategic Master Plan, Mission Area Plans, Mission Support Plan and other long range planning products. Mr. Neuman previously served as an Air Force officer for 21 years, with assignments in operations research; satellite command and control; launch operations; wargaming; and most recently in strategy, policy and planning development for the National Security Space Office, Pentagon, Washington D.C. Mr. Neuman is a graduate of Squadron Officer School, Air Command and Staff College and Air War College.

Notes:

[1] General Peter Pace, "The 16th Chairman's Guidance to the Joint Staff—Shaping the Future," 1 October 2005.

[2] SSgt C. Todd Lopez, "Moseley: We are moving towards interdependence with sister services," *Air Force Print News,* 13 October 2005

[3] Senator Wayne Allard, "The Greatest Threat to U.S. Space Dominance," *Space News,* 3 October 2005, 6a.

[4] Recent language in the Senate Arms Committee FY 06 Authorization Bill states, "The Committee directs the Air Force to provide its plan to improve space acquisition and re-establish the proud legacy of successful satellite development and fielding not later than January 31, 2006."

[5] For an excellent discussion of these issues, see the "Report of the Defense Science Board/Air Force Scientific Advisory Board Joint Task Force on Acquisition of National Security Space Programs ('The Young Panel')," or GAO-04-253T entitled 'Defense Acquisitions: Improvements Needed in Space Systems Acquisition Policy to Optimize Growing Investment in Space,' 18 November 2003.

[6] "Satellite Reconnaissance: Secret Eyes in Space," *Smithsonian National Air and Space Museum,* http://www.nasm.si.edu/exhibitions/gal114/SpaceRace/sec400/sec420.htm (accessed 21 October 2005)

[7] James Jay Carafano, Ph.D., Jack Spencer, and Kathy Gudgel, "A Congressional Guide to Defense Transformation: Issues and Answers," Heritage Foundation, 25 April 2005.

[8] Ibid.

[9] GAO-05-155, "Technology Development, New DoD Space Science and Technology Strategy Provides Basis for Optimizing Investments, but Future Versions Need to be More Robust," January 2005.

[10] Mr. Tom Young, et al, "Acquisition of National Security Space Programs, One Year Review," (briefing, 15 June 2004).

[11] GAO-03-1073, "Defense Acquisitions Improvements Needed in Space Systems Acquisition Management Policy," September 2003.

[12] National Security Space Acquisition Policy 03-01(NSS 03-01), "Guidance for DoD Space System Acquisition Process," 27 December 2004, section E4.9.a, 40; NSS 03-01, section AP1.2.5, 12.

[13] This analysis is a preview of the DoD chapter in the forthcoming *AAAS Report XXX: Research and Development FY 2006,* a comprehensive look at the President's budget for R&D in FY 2006. More tables and continually updated supplemental materials on R&D in the FY 2006 budget can be found on the AAAS R&D Web site at http://www.aaas.org/spp/rd

[14] Report of the Defense Science Board/Air Force Scientific Advisory Board Joint Task Force on Acquisition of National Security Space Programs ("The Young Panel"), May 2003, 14.

[15] GAO-05-891T, "Space Acquisitions: Stronger Development Practices and Investment Planning Needed to Address Continuing Problems," 12 July 05, 2.

[16] Report of the Defense Science Board/Air Force Scientific Advisory Board Joint Task Force on Acquisition of National Security Space Programs ("The Young Panel"), May 2003.

[17] GAO-05-891T, 2.

[18] Report of the Defense Science Board/Air Force Scientific Advisory Board Joint Task Force on Acquisition of National Security Space Programs ("The Young Panel"), May 2003.

[19] Young, et al., n.p.

[20] Ibid., n.p.

Network-Enabled Program Management: Meeting the Space Acquisition Challenge

Lt Col Thomas A. Doyne, USAF,
Transformations Strategist OSD/OFT
Mr. Mike Hurley, Naval Research Laboratory,
TacSat-1 Program Manager
Mr. Thom Davis, Air Force Research Laboratory,
TacSat-3 Program Manager

Today's post 9/11, Global War on Terrorism (GWOT) environment is truly the best of times and the worst of times for us in our Nation's space community. On the one hand, recent technological and organizational innovations such as the Joint Direct Attack Munition (JDAM) and the Director of Space Forces (DIRSPAFOR) have dramatically increased space's contributions to success on the battlefield. But the budget realities of the GWOT have placed renewed scrutiny on the way we, the national space community, acquire space systems. For example, the continued cost growth in Space Based Infrared System (SBIRS)-High has triggered another Nunn-McCurdy certification of the program to Congress. Table 1 is a listing, compiled by the Government Accountability Office (GAO), of the various problems associated with current space acquisition efforts.[1]

Problems	Systems Affected by One or More Problems
Requirements—Defining what the system needs to do and how well it needs to perform • Program did not adequately define requirements • Unresolved conflicts among users on requirements • Frequent changes made to requirements after product development began	• DSP replacement programs • Milstar • AEHF • SBIRS-High
Investment Strategy—Choosing a path that offers the most cost-effective solution and ensuring costs are contained • Program did not adequately analyze investment alternatives • Cost and/or schedule estimates were optimistic • Funding was unstable	• DSP replacement programs • SBIRS-Low/STSS • Milstar • AEHF • SBIRS-High • GPS III
Acquisition Strategy—Maximizing competition and contractor reliability • Level of competition was reduced or eliminated • Contract type was not suitable for work being done • Poor oversight over contractors	• AEHF • SBIRS-High • SBIRS-Low • STSS • EELV
Technology—Ensuring technology is mature before heavy investments are made in the program • Technology not sufficiently mature at program start • Software needs poorly understood • Testing compressed, skipped, or done concurrently with production	• DSP replacement program • Milstar • SBIRS-Low • AEHF • SBIRS-High

Table 1. Common problems identified in recent GAO reports.

No wonder then, Dr. Ronald M. Sega, Under Secretary of the Air Force, executive agent for Space recently gave a speech highlighting the need to get "back to basics" in space acquisition.[2] This article focuses on how network enabling technologies can allow us to get "back to basics" in the program management aspects of space acquisition with an acquisition staff 60 percent the size it was prior to the acquisition reform of the 1990s.[3] First, a brief background on the space acquisition reform of the 1990s will be presented to highlight the challenges of space acquisition. Next, Carrier Task Force 50 will be utilized as a case study on how network enabling technologies helped transform military operations. The results of this case study will be applied to the design review process of space acquisition. Recent experiences with the Tactical Satellite (TacSat) series of experimental satellites show the transformational promise that network enabling technologies and techniques hold for keeping space programs on cost, on schedule, and on performance.

Space Acquisition Reform in the 1990s

With the fall of the Berlin Wall and the end of the Cold War, the US military began a process of down-sizing and the space community was not exempt. As part of these efforts, the space acquisition community adopted the policy of Total System Performance Responsibility (TSPR). Under TSPR, the government program management role morphed from "oversight" of contractor performance to "insight" of contractor performance. Thus TSPR would allow the smaller space acquisition community to continue to manage the procurement of the next generation of space systems. The traditional acquisition method of sequential design reviews at decisive points in the design, development, assembly, test, and launch of a space system was and is manpower intensive. TSPR was supposed to allow the newly reduced government acquisition community to manage the development of our next generation space systems. Using operational terms, the unintended consequence of TSPR was a loss of situation awareness by the government during the acquisition process. According to the GAO, program managers and other working-level acquisition officials subsequently lost authority to the point where their ability to succeed on development programs was reduced. This loss of situation awareness was one of several factors in the cost and schedule over-runs experienced in our space acquisition efforts.[4]

In late 2004, National Security Space (NSS) Acquisition Policy 03-01was put into effect and it mandates the use of System Requirement Reviews (SRR), Preliminary Design Reviews

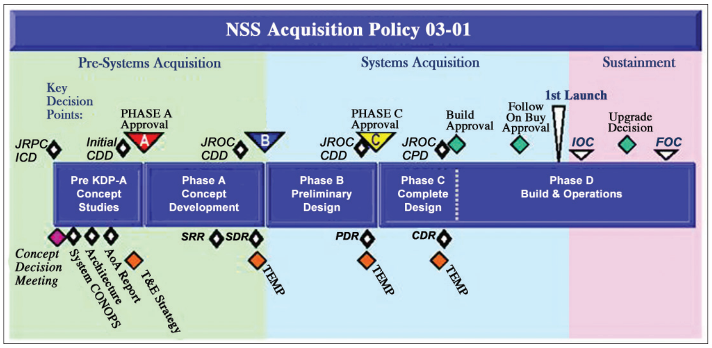


Figure 1. NSS Acquisition Process.

(PDRs), and Critical Design Reviews (CDRs) in parallel with the Joint Requirements Oversight Council process as depicted in figure 1.[5] Dr. Pete Rustan has elegantly captured the challenges of the SRR/PDR/CDR process in figure 2.[6] Fundamentally, he shows the impact of identifying problems too late in this process.

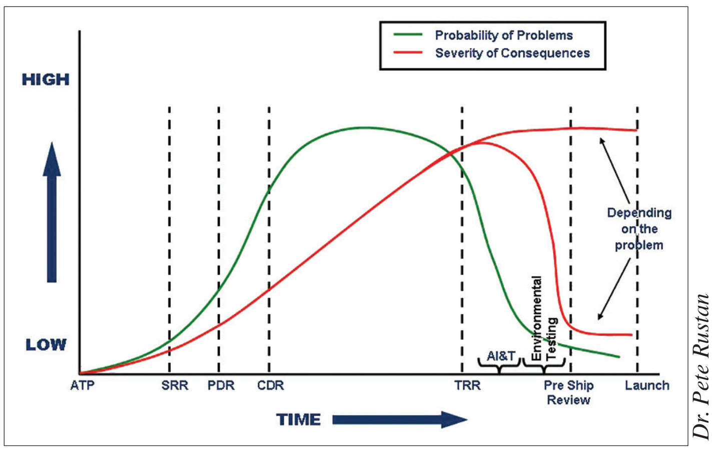


Figure 2. Problems and consequences of space acquisition.

Today's space program managers face the challenge of implementing this process and solving problems with staffs much smaller than those available prior to the mid 1990s acquisition reform. Fortunately, networked-enabled military operations provide us insights on how to meet this challenge. Specifically, Carrier Task Force 50 (CTF-50) and its success in Operation Enduring Freedom (OEF) is an instructive case study with lessons that are applicable to space program management.[7]

Carrier Task Force 50

Having departed the West Coast in August 2001, Carrier Group Three (CARGRU 3) was commanded by Rear Adm Thomas E. Zelibor and its main components consisted of the nuclear aircraft carrier USS Carl Vinson (CVN 70), Destroyer Squadron Nine (DESRON 9) and Carrier Air Wing Eleven (CVW 11). However, the events of 9/11 transformed CARGRU 3 into a modern day armada called CTF-50 and this armada eventually comprised 59 ships from six nations, including six aircraft carriers. CTF-50 employed network-enabling technologies that facilitated the command and control challenges presented by conducting coalition combat operations across an area stretching over 800 nautical miles.

Prior to taking command of CARGRU 3, Admiral Zelibor grasped the implications network-enabling technologies such as Knowledge Web (KWeb) after having utilized these type of tools in Global Wargame 2000. Upon assumption of command, Admiral Zelibor decided to implement KWeb and another SECRET Internet Protocol Router Network (SIPRNET)-based tool called CommandNet in CARGRU 3. These tools were developed from a need for group situation awareness and were designed to propagate critical incidents throughout a distributed force. During the work-ups prior deployment, Admiral Zelibor and his staffs were able to develop tactics, techniques, and procedures (TTPs) to take advantage of these new tools. According to Admiral Zelibor:

> The knowledge web enabled us to do what industry already is doing - the five "C's." Across the battle group, we correlated data; had a common picture of issues or situations; collaborated on experiences; acted corporately; and continuously learned. Essentially, this web made us faster, and the value was expressed by legendary war strategist Sun Tzu: "War is such that the supreme condition is speed."[8]

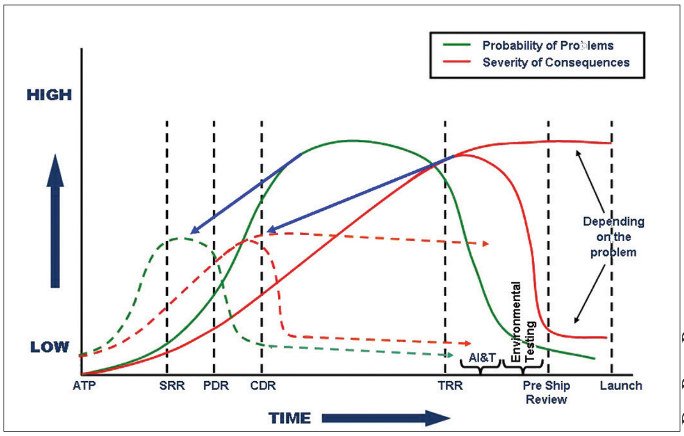
KWeb provided tailored information flow via Secure Chat for time-sensitive information for the tactical action officers. The Chat Rooms also provided for ad hoc requirements and support functions. Additionally, the Web-based "CommandNet" was utilized for critical events logs which provided command situation awareness. Various web pages provided analytical details and further information upon demand.

The impact of these network-enabled TTPs was a significant reduction in paperwork and "PowerPoint slideology" with a corresponding increase in efficiency and effectiveness. The daily operations summaries and intelligence updates were a perfect example. Prior to KWeb, the operations staffs across a CTF would spend much of the night preparing a daily intentions message that ended up in large unwieldy tabbed information notebooks. With network enabling tools such as KWeb, users across CTF-50, and even back in the United States, could "pull" the information they needed. Thus, commanders and staffs came to the daily staff meetings with a high degree of situation awareness. In addition, they briefed off of their web pages as opposed to creating separate PowerPoint charts. As a result, Admiral Zelibor's daily staff meeting/intelligence update became a forum to discuss fleet tactics and strategy, vice being an exercise in giving everyone a snap-shot of yesterday's status. To quote one commanding officer of a cruiser in CTF-50: "I didn't read a single intentions message." KWeb became known as the "go to" place for the most recent and accurate information regarding the operation. Moreover, multiple services, government agencies, ships, and land based installations were able to timely access information in ways impossible utilizing more traditional record message traffic or e-mail.

The main impact of the time gained from this more efficient decision-making progress was an increase in the amount and quality of contingency planning—anticipating the "what ifs" of combat operations. As OEF progressed, CARGRU 3 staff was able to enact well thought out plans, rather than improvising and reacting to changes in the war. During OEF, the staff developed 35 war plans of which 33 were executed.

Implications for Program Management

While acquisition and program management do not have the immediate life and death implications of combat operations, many of the lessons learned from CTF-50 can be applied to space acquisition. Any program manager to be successful, like any combat commander such as Admiral Zelibor, must get their geographically dispersed acquisition team to correlate data, create a common picture, collaborate, act corporately, and continuously learn. Network-enabling technologies, coupled with proper training and TTPs, have the potential to identify problems and develop solutions much earlier in the acquisition process. The impact of this would be to flatten and move to the left the space acquisition problems and consequences curves created by Dr. Pete Rustan as shown in figure 3. Network-en-



Dr. Pete Rustan

Figure 3. Impact of network-enabled capabilities.

abling technologies and TTPs *cannot replace* sound leadership and engineering decisions in acquisition, any more than network-enabling technologies and TTPs can replace sound leadership and judgment on the battlefield. Additionally, network-enabled tools and procedures should be able to reduce the onerous administrative burdens traditionally associated with the SRR/PDR/CDR process, much in the same way the KWeb and CommandNet greatly reduced the same type of burdens on the staffs preparing for Admiral Zelibor's daily staff meetings. The following vignettes from our experiences with TacSat-1 and TacSat-3 show how network-enabled program management can create the conditions for success in space acquisition. In fact, the compressed cost and schedules associated with the TacSat series of satellites could not be and cannot be met without these transformational tools.

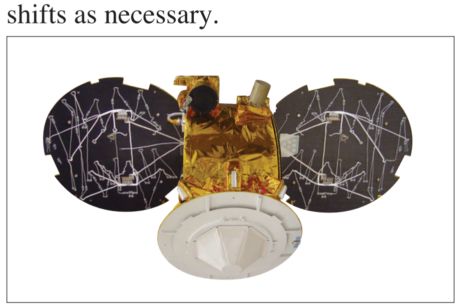
TacSat Lessons Learned

Within the space community, a "carpool" consisting of the Office of Force Transformation, Naval Research Laboratory (NRL), the Air Force Research Laboratory (AFRL), Air Force Space Command (AFSPC), Space and Missile Center (SMC), among others, has been created to experiment with a series of small (less than 500 kg) yet capable satellites in close cooperation with geographic combatant commands such as Pacific Command. TacSats are intended to examine the feasibility and utility of rapidly (and economically) developing small satellites with capabilities relevant to warfighter needs at the operational and tactical levels of war. To do this, TacSats will experiment with technology-operational concept pairings in order to refine the technology *and* to refine the tactics, techniques and procedures the warfighters use to employ the technology. To restate this – TacSat experimentation will help both the acquisition and the warfighting communities discover the best "application" of the technology. Both TacSat-1 and TacSat-3 are useful case studies, as TacSat-1 has been built and is in storage awaiting launch while TacSat-3 has just begun the design process.

TacSat-1

As the inaugural TacSat, TacSat-1 has succeeded at setting an example for future small, low cost, and operationally relevant TacSat experimental missions. NRL built TacSat-1 in only 12 months for $9.3 million, plus $5 million in surplus hardware. TacSat-1 is designed to operate on orbit for 1 year and is currently in storage awaiting launch. By greatly reducing developmental costs, the use of a surplus ORBCOM satellite bus proved a powerful example of the benefits of utilizing a standard bus. TacSat-1 contains an emitter identification payload coupled with an ultrahigh frequency (UHF) cross-platform link and low resolution visible and infrared (IR) cameras. PACOM will use TacSat-1 to experiment with tasking and data dissemination via SECRET Internet Protocol Router Network (SIPRNET) either as a stand-alone sensor or tiered with airborne sensors such as an EP-3 or RJ-135.

NRL used several net-centric approaches to meet the cost and schedule challenges during the development of the TacSat-1 spacecraft, aircraft equipment, and ground station. Although the spacecraft bus and Space Ground Link System (SGLS)/Consultative Committee for Space Data Systems (CCSDS) ground station standards are incompatible with Transmission Control Protocol/Internet Protocol (TCP/IP), the payload controller uses LINUX OS and runs most payload components using shell scripts over TCP/IP Ethernet. This configuration allowed software development and thorough testing of the qualification and flight payload hardware to be performed with team members dispersed between Florida and Washington, D.C. At least one person on-site was needed, particularly in the first few weeks of setup, for turned on-offs, resets, certain configuration changes, and so forth. The benefits of this network-enabled development and testing included increasing access to quality labor pool, effectively ramping quality software personnel up and down, increasing the hours the software development occurred with hardware to test against, and easily modifying or adding work shifts as necessary.



TacSat-1 Composite Deployed.

The TacSat-1 team also used a Web-based project management site iteratively developed for NRL, largely by Praxis Inc., over several years and projects. Thus, the site and its associated capabilities procedures were well known and understood by the TacSat-1 team. This Web-based tool provided secure login, a library area with document configuration and access tools, an on-line calendar used to communicate major program events, graphical file transfer protocol (FTP), and chat tools. At a program level, this website routinely proved excellent for communicating major activities and collaborating/coordination design reviews. The day-to-day value of this tool varied with respect to each of the teams within the project, with geographically separated groups tending to use this tool most often, while local groups often found email a more effective tool for collaboration. This project management website is also proving invaluable for NRL's management of their phase of the standardized bus effort. Over eight companies all over the country are collaborating on system engineering tasks in preparation for the next major systems requirements review. In this instance, the project web site is proving to be the tool of choice for collaboration and is used extensively in conjunction with weekly telecons.

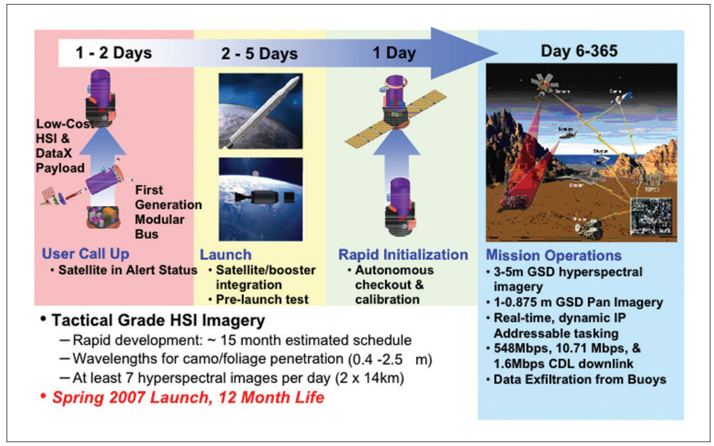
TacSat-3

Building on the experiences with TacSats-1 and -2, TacSat-3 is the first to have gone through a formal payload selection process with AFSPC and Combatant Commands (COCOMs). Users provided capability gaps/shortfalls and ultimately a general officer team who made the final payload selection. A building block for Operationally Responsive Space, TacSat-3 will experiment with a Hyperspectral Imaging (HSI) capability direct to the tactical warfighter within 10 minutes of a collection opportunity.

Design constraints established for the TacSat-3 program include a total program cost to be less than $50 million, to fit on a low cost responsive space booster and a satellite weight of less than 400 kilogram, mission life goals are 6-12 months, with a build time for payload and modular bus of less than 18 months.

The TacSat-3 experimentation features a low cost plug and play modular bus and low cost militarily significant payloads—a hyperspectral imager and secondary payload data exfiltration provided by the Office of Naval Research. The key objectives are rapid launch and on-orbit checkout, theater commanding, and near-real time theater data integration. TacSat-3 will experiment with capabilities and processes including a rapid response to a user defined need for target detection and identification, camouflage defeat, identification of concealment and disturbed earth, and battle damage assessment. It will also feature a rapid development of the space vehicle and integrated payload and spacecraft bus by using components and processes developed by the Operationally Responsive Space modular bus. The mission provides traceability for a rapid deployment from call-up for launch to theater control within seven days and responsive delivery of decision-quality information to operational and tactical commanders by enabling tactical tasking and data delivery.

TacSat-3 follows the TacSat experimental series philosophy of providing COCOMs realistic opportunities for responsive,



TacSat-3 Concept tactical target responsive launch, checkout.

dedicated space capabilities at the operational and tactical level. The TacSat-3 spacecraft will collect and process images and then downlink material identification (ID) text and geolocation or downlink full data image using the already fielded and established Common Data Link. An in-theater tactical ground station will have the capability to uplink tasking to spacecraft and will receive full data image. The TacSat-3 HSI payload will conduct spectral reconnaissance and surveillance fused with high resolution panchromatic (PAN) imaging. Depending on how rapidly TacSat HSI spectral products are generated, the system may be able to cue other sensors or respond to tip-offs or cues from other intelligence, surveillance, and reconnaissance (ISR) assets.

A key component for the responsive space initiative is to leverage plug and play technologies to develop a fully modular bus. Funded by the Department of Defense (DoD) Office of Force Transformation, TacSat-3 will focus on the first generation of modular bus technologies. Goals of the modular bus are compliant with standard interfaces and modular subsystems. Additional objectives are a flexible data bus, plug 'n play switch fabric, modular solar arrays, scalable power, and adaptable to all orbits. Four contractor teams are developing a preliminary design and competing to be the TacSat-3 bus provider. The selected team will be required to fabricate the actual TacSat-3 modular bus within just ten months following task award.

Although still early in the design process, the TacSat-3 program has identified several challenges related to communications within a geographically separated government and contractor team. The primary payload contractor, Raytheon, has established a website to share files with the government systems engineering team. This allows the team insight directly into the Raytheon processes and designs, and eases information flow. A need was recognized to share information on a system with government control amongst the entire TacSat-3 team. The Aerospace Corporation established an FTP site which acts as a common hard drive with special features. The FTP site has protections to protect proprietary information. Additionally, a file structure for official files was established with only a limited number of personnel with write access. These communication tools have been invaluable in sharing information quickly and accurately, especially in the design and construction of the HSI payload. In addition, these tools are expected to play a vital role in allowing the TacSat-3 program to meet its ten month schedule with less than a mission cost of $50 million.

Conclusion

Today's national security space community faces the challenge of providing vital space-based capabilities to users ranging from the White House to our fielded forces. Compounding these challenges are factors such as a smaller space acquisition community than in years past and greater scrutiny from Congress, the press, and the public because of the significant cost and schedule over-runs experienced by most of our current space endeavors.

Lessons learned from our military operations in the GWOT with respect to network-enabled operations offer useful insights to our space acquisition community on how to meet the challenges of providing space-based capabilities on-cost and on-schedule. We can utilize network-enabling technologies, as did CTF-50 in OEF, to correlate data, create a common picture, collaborate, act corporately, and continuously learn. Network-enabling technologies, coupled with leadership, training and TTPs, have the potential to identify problems and develop solutions much earlier in the acquisition process. As we are learning from the TacSat satellites, these technologies will enable us to "get back to basics" and provide critical space-based capabilities in a timely and cost-effective manner.

Notes:

[1] United States Government Accountability Office, *Report to Congressional Committee: Military Space Operations: Common Problems and Their Effects on Satellite and Related Acquisitions,* 5, http://www.gao.gov/new.items/d03825r.pdf (accessed 10 October 2005).

[2] Nathan Hodge, "Sega Promises 'Back To Basics' In Ongoing Satellite Review," *Defense Daily* 227, no. 60, http://www.defensedaily.com (accessed 29 September 2005)

[3] *Report of the Defense Science Board/Air Force Scientific Advisory Board Joint Task Force on Acquisition of National Security Space Programs,* 23-24, http://www.fas.org/spp/military/dsb.pdf (accessed 10 October 2005).

[4] Ibid., 1.

[5] *National Security Space (NSS) Acquisition Policy*, no. 03-01, 27 December 2004, 5, http://akss.dau.mil/docs/Space%20Acquisition%20NSSAcqPol0301_signed_%2027Dec04%20(GN).pdf (accessed 10 October 2005).

[6] Dr. Pete Rustan, *US Defense Space Acquisition Problems and Potential Solutions* (address, Defense Acquisition Performance Assessment Project, slide 4, 15 September 2005).

[7] Dr. Mark Adkins and Dr. John Kruse, *Case Study: Network Centric Warfare in the U.S. Navy's Fifth Fleet, Web-Supported Operational Level Command and Control in Operation Enduring Freedom,* University of Arizona, 03 August 2003, http://www.oft.osd.mil/initiatives/ncw/docs/CTF50_NCW_Case_Study.pdf (accessed 10 October 2005) and CAPT Neil Parrot, USN, *CTF-50 Case Study* (lecture, Network-Centric Operations Short Course, Tysons Corner, Virginia, 14 September 2005), CD-ROM.

[8] Rear Adm Thomas E. Zelibor, "FORCEnet Is Navy's Future. Information-Sharing, From Seabed To Space," *Armed Forces Journal*, December 2003), www.chinfo.navy.mil/navpalib/.www/rhumblines/rhumblines170.doc

Lt Col Tom Doyne is assigned to Force Transformation in the Office of Secretary of Defense. Previously, he attended the Geneva Centre for Security Policy's International Training Course. He commanded 12 SWS at Thule Greenland prior to attending SDE. His background includes satellite, missile warning and launch operations.

Mike Hurley (BS, Engineering, Virginia Tech; MBA, George Mason University) is the head of the Spacecraft Development Section at the Naval Research Lab (NRL) in Washington D.C. Since 2002, Mr. Hurley has been working to mature Operationally Responsive Space (ORS) concepts and processes thorough iterative, operational experimentation such as the TacSat experimentation. Mr. Hurley has helped shape several of the ORS concepts and helped define the primary objectives of several TacSat experiments. He is currently the program manager of the TacSat-4 experiment which includes a prototype implementation of the Phase III ORS/JWS (spacecraft) Bus Standards as well as continued integration of space assets into tiered, tactical systems for netcentric effects.

Thom Davis (BS, Louisiana Tech; graduate degrees, Gonzaga University and Central Michigan University) is AFRL's Space Vehicles Directorate TacSat-3 program manager. He is responsible for all aspects of the responsive space initiative to demonstrate Hyperspectral imaging with a low cost satellite allowing direct tasking by operational theater commanders. Previously, he was program manager for the XSS-10 flight experiment which was the first ever microsatellite to successfully demonstrate autonomous navigation and on orbit proximity operations. XSS-10 received numerous awards including the 2003 Air Force Science and Engineering Award for Exploratory or Advanced Technology Development and the AIAA Space Systems Award for 2003. He was a member of the Georgia Institute of Technology research faculty from 1997 to 2003. Additionally, Mr. Davis spent 22 years in the United States Air Force, retiring as the Acting Director of Space and Missiles Technology at Phillips Laboratory. He also served as the Deputy Director of Program Management at the Air Force Space Technology Center. A command pilot, Mr. Davis had operational assignments flying the HH-3E and UH-1N helicopters, and the KC-135 tanker, including a tour with the 89th Military Airlift Wing (Presidential) at Andrews Air Force Base. He is a senior member of AIAA and lifetime member of the Air Force Association and the Dadaelians.

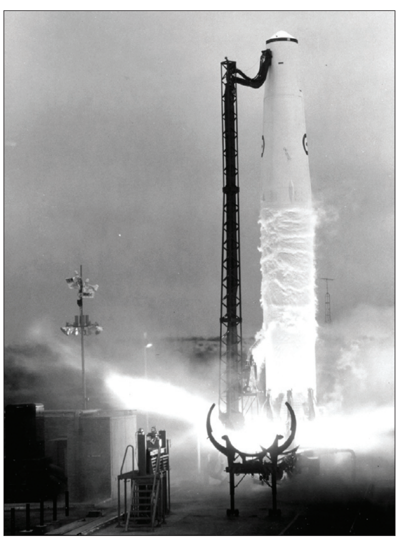
Interview with an Original Member of the Western Development Division

Mr. Robert Mulcahy
Historian
Space and Missile Systems Center

Air Force Space Command's acquisition arm, the Space and Missile Systems Center (SMC), originated during the Cold War on 1 July 1954 as the Western Development Division (WDD) of the Air Research and Development Command (ARDC). Brig General Bernard Schriever (1910-2005) was the first commander of WDD and is considered by many to be the father of the Air Force space and missile programs. At first, the WDD headquarters were temporarily established at a former church and its parochial schoolhouse in Inglewood a few miles from Los Angeles International Airport.

The original WDD mission was to develop America's first operational intercontinental ballistic missile (ICBM) system as rapidly as possible. If the Soviet Union produced a significant number of operational ICBMs before America, communism could have gained a decisive strategic advantage over the free world. With the possibility of a Soviet ultimatum or even a nuclear war in the balance if the United States failed to produce an operational ICBM system, the Air Force mission in Los Angeles could not have been more vital.

Developing the ICBM was a top military priority at that time and required many of the nation's best scientists and engineers. The Ramo-Wooldridge Corporation was a private company that was chosen in 1954 to provide WDD with technical direction and systems analysis for the development of the ICBM. In 1958, Ramo-Wooldridge merged with Thompson Products to form Thompson-Ramo-Wooldridge (TRW).



The first launch of a Thor Intermediate Range Ballistic Missile (IRBM) takes place at Vandenberg AFB, California, on 16 April 1959.

WDD increased its personnel, its facilities, and its mission within a short time. ARDC added the responsibility for developing the first military satellite system to WDD on 10 October 1955. It took WDD (and its successor organization, the Air Force Ballistic Missile Division) only five years to develop the Atlas ICBM and the Thor Intermediate Range Ballistic Missile (IRBM) and bring them to initial operational capability in 1959 to counter the Soviet threat. WDD pioneered the development and acquisition of the Air Force's first ICBMs, satellites, and launch vehicles.

Air Force Capt David Fleming is a World War II veteran who became one of the original members of General Schriever's "Schoolhouse Gang" at the Inglewood headquarters in 1954. Captain Fleming was involved in the 1954 contract negotiations between the Air Force and the Ramo-Wooldridge Corporation, and he was the first procurement officer assigned to WDD. Fleming's name is inscribed on the WDD Rock at Los Angeles AFB that commemorates the first 18 Air Force members who were hand-picked for assignment to WDD in 1954. SMC historian Robert Mulcahy interviewed Mr. Fleming on 5 April 2001.

Capt David Fleming of WDD, 1954.

INTERVIEW

Mulcahy: Mr. Fleming, how were you chosen for your assignment to WDD?

Fleming: I was recalled back to active duty in 1949 because I'd been to school under the G.I. Bill and got a reserve officer's commission… They sent me up to Newfoundland at Pepperel AFB to replace an officer up there who was qualified to fly the F-86… While we were in Newfoundland, my wife had a baby boy, but she went into a postpartum psychosis. They flew our family back down to Walter Reed Hospital in Washington, D.C. They released her thinking that she was OK and they sent us back up to Newfoundland. It was shortly clear that she needed extensive treatment, so in 1952 they transferred me down to Baltimore to the ARDC, so I could be near her at Walter Reed Hospital.

After reporting to ARDC, they assigned me to be a contracting

The first Western Development Division (WDD) commander, Bernard Schriever (commander from 1 July 1954 to 31 May 1957), in a 1959 photo as a lieutenant general. General Schriever was a brigadier general when he became the commander of WDD and left as a major general.

officer for research and development contracts. That's what I was doing when I met, then, Colonel [Bernard] Schriever. I'd been working on a lot of special assignments for research and development contracts. I had 10 contracting officers that had been assigned from another ROTC [Reserve Officers Training Corps] program at MIT [Massachusetts Institute of Technology] and Harvard Business School. Officers applied from each school. So, that was my team.

Then I was approached by Colonel Schriever. He was in the Office of the Secretary of the Air Force in Washington, [D.C]. They had some special contracts that they awarded directly out of the headquarters, but they didn't have any contracting officers or administrators. ARDC was assigned to assist USAF headquarters in the negotiation and administration of selected contracts for unique research and development projects with nonprofit organizations, private corporations, consultants, and major public and private universities. I was the administrative officer for the RAND [Research and Development Corporation] Corporation contract, which was a very major contract for the Air Force as well as for the RAND Corporation. We also negotiated and administered contracts with Western Electric, Bell Laboratories, MIT, and AGARD – the Advisory Group for Air Research and Development based in Europe. AGARD had a lot of European scientists making themselves available for advice and counsel to the Air Force. The Army brought Wernher von Braun to Huntsville. The Air Force had access to a lot of European scientists who preferred to stay in Europe. I handled the AGARD contract, and I talked to Colonel Schriever several times. While I was at the AGARD meetings in 1954, we discussed his observations of the problems and negotiations for the research contracts.

When I returned to ARDC, Colonel Schriever gave me a call. He had a new project in process, and it turned out to be the key project of the time. He wanted to talk to me in Annapolis where we met in the Officers' Club at the Naval Academy. In the discussion, Colonel Schriever said that he was putting together a small team of people (about a dozen) to take on the administration and coordination of a new contract. It was going to be issued for the research, development, and production of a new intercontinental ballistic missile. The project would be based in California and he asked if I was interested. He wanted me to take on the assignment as the procurement officer. It was shortly after that when I told him to count me in. It sounded like an exciting assignment. He said, "I'll get back in touch with you and let you know when we're going to initiate this project." I found out the next week when I got a call to go up to General [Donald] Putt's office at ARDC and met with Dr. [Simon] Ramo and Dr. [Dean] Wooldridge.

Mulcahy: Were you involved in the contract negotiations with the Ramo-Wooldridge Corporation [R-W]?

Fleming: The negotiation I'm privy to was the Air Force contract with the Ramo-Wooldridge Corporation. It put this technical organization together between R-W and the Secretary of the Air Force. Ramo and Wooldridge were on his Scientific Advisory Board. At the time I got into the game, I was ordered up to General Putt's office to meet these two gentlemen. That was the first time I met with either Ramo or Wooldridge and they already had the quid pro quo established. They had formed a new company: Ramo-Wooldridge [Corporation]. They had incorporated in Delaware. They showed me the incorporation papers, which I needed in order to start drafting a contract.

I ran into a security problem. Their corporation had no security clearance since R-W had only been formed a week prior, and they had no facilities to inspect for the security of classified documents. It all had to be reinvented on how I could give them a classified, Top Secret contract, a letter contract, which would cover them so they could go to Ohio and negotiate with Thompson Products to bring about a merger, so they would have the financial backing of a major corporation with the facilities and the experience. This marriage was arranged in Washington, D.C, not in my office.

My instructions were, "Do what you can, and give R-W a letter-of-agreement contract to convince Thompson Products that this has been officially awarded by the Air Force to R-W

Simon Ramo (left) and Dean Wooldridge in front of their company's first location at a former Los Angeles barbershop in 1955.

and Thompson." The letter contract wasn't on the back of an envelope type thing. I don't want to make it sound like that. I was only invited to come in to this because at this point R-W needed to have a contract. An awful lot of conversations should have, and could have, and probably did take place down at the Pentagon, but I wasn't privy to that.

Mulcahy: Did you have a precedent to use as an example when you contracted with Ramo-Wooldridge?

Fleming: No. I had several citations from the AGARD Committee and everybody else. It was one of the things that came to me instinctively. It was amazing. I'm not a legal student, but government procurement practices were something that I became very well versed in. You didn't have enough time to ask questions about "what if?" Ramo and Wooldridge were there and they were going to leave the next day and go to Ohio and sign a deal with Thompson Products. That was the highest priority in the government at that time, so I had to get them on board.

Mulcahy: How much authority did you have to make decisions when you negotiated this contract?

Fleming: I could sign anything up to $50 million. The major funding for this contract and the ratification of it was taken over. I continued to be the administrative contractor for the R-W contract. All the other contracts, like for the Atlas project, were required to be handled out of Air Materiel Command at Wright-Patterson [AFB], for all I know.

Mulcahy: What were some of the main challenges in negotiating the contract with Ramo-Wooldridge?

Fleming: Trying to educate a couple of guys that were technically brilliant about the nitty-gritty of government procurement regulations (laughs). Wooldridge and Ramo couldn't understand why they couldn't have everything they wanted. They were really pumped up. They wanted a classified Statement of Work in their contract. They said, "Maybe you can call somebody to approve it." I said, "Nobody is going to approve anything that I'm going to sign but me. It will go up, but until I sign off on this contract, there's nobody I can call." We played hardball. That was sort of the relationship all the way through the negotiations. They always felt that anybody that didn't hop to it when they wanted to get something done was an obstructionist. But they got over it and they turned out to be nice guys.

They were upset because Thompson Products, being a government contractor and a manufacturing company, couldn't benefit by the decisions being made on our procurement of the project. Ramo and Wooldridge were sitting on the review board and now they were going to be part of Thompson Products. I didn't feel that it made any sense to allow them to be able to review the bidding on anything their company could benefit in. I just excluded them from participating in any project that TRW (which was the new company name) produced. They weren't eligible to benefit due to the fact that they were the technical overseers. They took it up the line on appeal, but I got backed

Formerly St. John's Catholic Church and school, these buildings housed WDD in the first six months after its creation.

up all the way by Schriever and the Secretary of the Air Force's office. I guess if you sit on the Board of Advisors to the Secretary of the Air Force, you'd have a hard time understanding when some captain can just say something and make it stick…

They [Ramo and Wooldridge] were successful in attracting some brilliant people in the field of aerospace, propulsion, chemistry, and warheads. Whatever it was. You name it. These two guys found it easy to recruit employees. It wouldn't have been that way if they just had none-scientific-minded individuals. They gave a certain character to the project, which made it attractive for people to come to work for them. If you can't get people to work for you, you're not going to go anywhere.

Mulcahy: How long did it take you to complete the Ramo-Wooldridge contract?

Fleming: It took me a day to sit down with Ramo and Wooldridge, and it took me another day to draft it. The next day they were off to Ohio to meet with Thompson [Products] where the copy of the letter came from. A lot of the decisions came during the next meeting: how they got paid, when they got paid, who had to approve this and that, what clearances were required, and our priority to get a clearance on their facility. Once everything was wrapped up, which was about a week or 10 days later (which was amazing) I was able to go out. They had the correct facility protection devices installed and the safe to store whatever documents were necessary. Administratively, it went rather smoothly as far as my small part of the program was concerned.

Mulcahy: What did you do after you finished the Ramo-Wooldridge contract?

Fleming: From then on, it became administration. There was a series of requirements, which R-W kept coming to me to get approved. They would make the evaluation on subcontracting and then the administration of those contracts was under

Wright-Patterson. The only contract I administered after that was interface contracts between the Air Force and R-W.

Mulcahy: Did General Schriever have any input into the Ramo-Wooldridge contract?

Fleming: No. Not to my knowledge. I never saw him. In fact, I didn't see him again until I was out in Hollywood. Colonel Schriever showed up almost the day after I arrived out there. He said, "How are you getting settled in?" I said, "Fine. I don't have an office. I'm trying to move my family into a house, but I'm OK." I was tempted to ask him, "Where are you going to put this [WDD] operation?" I got that answer the next day when he said, "We're going to put this [WDD] in what used to be a church and a Catholic school."

Mulcahy: What was happening with WDD in Los Angeles when you arrived there?

Fleming: There wasn't any WDD in May of 1954. I was assigned to a division [6590th Special Activities Squadron] in Hollywood. ARDC had to do some of their technical development of surveillance films. I didn't know what they were doing, and I didn't ask. It was an office that could administer my pay and relocation. I took care of things for the ARDC until WDD was actually activated.

I went out to Hollywood and rented a home in Inglewood for my family. I was in business, but I was all alone. The ARDC paid me out of Hollywood. Then in August 1954, I was officially assigned to WDD, when they activated it, along with all the other officers and personnel.

Mulcahy: Why did the Air Force choose Los Angeles for its WDD headquarters location?

Fleming: Ramo and Wooldridge were a very essential part of the business plan the WDD had. Ramo and Wooldridge wanted to locate the office in the center of their labor pool for the project. It was going to be West Coast-oriented, because the aerospace industry was located from Boeing in Seattle down to Southern California. That's where they decided to put the WDD. I don't know what discussions they had that led to that decision.

Mulcahy: When did you arrive at the church headquarters?

Fleming: In July, I was the only one there for awhile. R-W had a very small office in a shopping center up near the LA [Los Angeles] Airport. I think they had a staff of 12 people at the time.

Mulcahy: Why did WDD choose the former church in Inglewood as its headquarters?

Fleming: You got me (laughs). That's what I asked myself when I showed up. They said, "This is where they're going to put the offices." I thought, "Maybe they need more help with this project than I imagined." When we had the visitors from the board of advisors to WDD come out, including Jimmy Doolittle, somebody asked Si Ramo, "What are you going to do with the confessional booths?" He said, "When we have a real tough problem, we go there and pray." Nobody ever explained to me why they chose the church, and I never asked any questions after that. I figured, if this is where they want it, this is where it is. I don't know who arranged it.

Mulcahy: How did WDD use the church building?

Fleming: That was the main WDD building. They built offices in there. The main computer was up where the altar used to be, because we had the narthex (the high bay area that went all the way up to the roof in the church) with a big stained glass window behind it. The computer was about the size of a U-Haul van. It was considered the "super computer" in those days, but that's before transistors. We took the stained glass window out and put in a big fan. It looked like an airplane propeller. The fan pulled the heat out of there, because the vacuum tubes that were running out of that old-generation computer put out a lot of heat. It also created a problem for us in the church building. We needed to air condition the building but the Air Force disapproved it.

R-W didn't have any facilities yet. They were under construction. They eventually constructed the office space they needed in a very short period of time, but to get the project moving, we had a lot of scientists who worked for R-W in the church building. We just built some temporary office space for them. The engineering people were in the prefab [prefabricated] classrooms outside. When R-W eventually got office space for them, we tore those prefab buildings down and made more parking space for the headquarters.

Mulcahy: What did you typically work on while you were at WDD?

Fleming: I worked in the administration, not on projects. I was the procurement contractor who interpreted government regulations against the contracts that were being awarded. I did not select the contractor or do the negotiating.

Mulcahy: Tell me about the WDD Procurement Review Board.

Fleming: It was made up of the original WDD Air Force personnel who were out there. R-W was not involved in the first, main evaluation. The first meeting was to select a contractor for the Atlas missile. During our evaluation, the contractors made written presentations. We had their complete financial reports, profiles of their existing labor force, projections for the proposed project, and that type of thing. Our evaluation was based on the number of PhDs they had, the amount of space they had, whether they had any previous experience in the aerospace technology that was involved, how much manpower they had, how much recruiting they had to do, how much work space they had for engineers, and what their production record was in aerospace over the last 10 years. We gave certain weight to different factors. It was a qualification evaluation. We had to decide if this was new to them, or if we were dealing with people who could save us a lot of time by being ahead of the curve. As I recall, all the major aerospace companies were in on this evaluation. This included General Dynamics, Lockheed, Boeing, Douglas, etcetera.

We spent a whole day just evaluating these proposals that had come in from the major aerospace companies. The contractor (Convair) that got the program already had a missile they were developing under their own funds. That gave them the lead in the final analysis. I think the other aircraft industries suspected all along that we were going to go to them.

Mulcahy: Did WDD have privileged or unusual authority to get what it needed?

Fleming: They had full authority to get whatever they needed. Schriever was told that if he had any problems he could go up to President Eisenhower if he needed to.

We had a deal with Air Material Command at Wright-Patterson. When we had complaints about the need for air conditioning, Wright-Patterson turned down the request, so Schriever said to me, "Get on an airplane and go there and convince this colonel that we have got to have air conditioning." So, I drew up a justification for needing air conditioning. We couldn't afford to compromise the life of the computer, which, with its vacuum tube, was a horrible environmental situation. I made the request cover enough air conditioning equipment to air condition all the buildings. I had a meeting with the colonel, and it started out with him saying, "You will get air conditioning over my dead body!" But he ended up signing off on it. There was a whole lot of posturing going on in those days. When I visited Wright-Patterson everybody tried to find out, "What's going on out there anyway? How do you guys get away with getting all of this priority stuff?" But that was to be expected. Somebody had to set this thing [WDD] up. He [Schriever] was doing something right, because it was working.

General Jimmy Doolittle (left) and General Bernard Schriever at the dedication of the "WDD Rock" in 1964. The WDD Rock is currently located at Los Angeles AFB, and it lists the names of the original Air Force members of the WDD.

Mulcahy: How tight was the security at the WDD headquarters?

Fleming: It was tight, but it was all handled by R-W. They had a Pinkerton outfit come in and set up shop. If I forgot my pass card, I'd have to go back home and get it, because the security didn't go out of their way to let people through. They took their job seriously. Somebody put the fear of God in them. They wanted to make sure they didn't make any mistakes. I would say that security was very tight.

Mulcahy: Were you the only contracting officer at WDD while you were there?

Fleming: That's right. Remember, there were only 12 Air Force personnel there. It seemed like the Air Force had selected one person for each major administrative duty and everything else was being held by R-W.

Mulcahy: Why did General Schriever have such a small staff at WDD?

Fleming: I don't know what was behind his thinking. It was so contrary to my experience from how the government usually operates. The government usually had three or four people assigned to each task, but Schriever wanted a small cadre of people that he could identify with on a personal basis.

From the day Schriever asked me to join him, it was clear to me that he had his mind set on specific people for specific assignments in his organization. He didn't want a large group of people. He wanted contact with the outside world on various topics. He had [Col William] Sheppard, [Col Charles] Terhune, [Lt Col Benjamin] Blasingame, [Lt Col Beryl] Boatman, [Lt Col Philip] Calhoun, and the rest set up so they would interface with R-W people in certain categories of engineering, propulsion, or whatever the major categories of technology that R-W was handling. Schriever had no organization to manage. That would take up a lot of his time trying to cope with people problems. We all had our own secretaries and that was about it. We didn't have staff either.

Mulcahy: Did the Air Force personnel at WDD work long hours?

Fleming: Yes. I don't exaggerate, 10, 12-hour days were normal. The weekends were very iffy. You'd go to church everyday (laughs). Schriever was always working. He was the chief interface and he was back and forth to Washington trying to get this and that approved, and get funding allocations. He was a one-man band.

Mulcahy: How would you describe General Schriever as an officer?

Fleming: Any and every time I met him, which wasn't a dozen of times, I was really convinced that this guy's a born leader, and an officer and a gentleman in every sense of the word. He really got the best out of people… I had a lot of respect for him.

He could handle people very well. He didn't use his office to make them agree. He convinced them to agree. There wasn't time for petty arguments in this program. When I look back on it, I am amazed at how smoothly everything went.

Mulcahy: How closely did you work with Schriever while you were there?

Fleming: It wasn't on a day-to-day basis. Schriever assumed if I had any problems, I would come and talk to him. He didn't micromanage the situation. I really didn't have a lot of contact with him. I had plenty to do just to keep my head above water. That's one of the nice things about having a small team like that, nobody was competing for territory. You had all the territory you could handle, and then some. You had job satisfaction. You knew what your limits were, and you knew how to do the job. You were inspired to do the best you could and it worked.

I was only there a little over a year. My personal problem manifested itself to the point where… I had a regular commission as a captain, and I was really caught up in this program. But I really had to put the family first in this situation and send my resignation. I moved back to the ARDC headquarters on March 1, 1955.

Mulcahy: Was WDD still in the church when you left?

Fleming: Yes. After I left Los Angeles, I went back to ARDC headquarters. Then I got a GS-12 job until I could join industry somewhere. The first job I had after that was in Denver with the Titan Program as the procurement contract director.

Mulcahy: How would you describe the accomplishments of WDD while you were there?

Fleming: I think we did a terrific job. I would say, if anybody had to set up a program in the future that had anywhere near the order of magnitude that this did, they could take a lesson. Keep your organizing team small and don't bring any more people into the situation than you have to, because it's going to get loaded down with bureaucrats and so-called "helpers," consultants, all kinds of things.

Mulcahy: How do you feel about having your name listed on the WDD Rock?

Fleming: I love it! It came as a big surprise to me. I got invited to the dedication ceremony in 1964 and they sent me a copy of what's on the Rock. This was a function of the Air Force Association, I found out, not the government or TRW or anybody else. I think recognition is flattering to anybody. This is a very small rock, but it's the only rock I got (laughs).

Mulcahy: I would like to thank you for your time.

Robert Mulcahy (BA and MA, History, California State University at Fullerton) is a historian for the Space and Missile Systems Center, a subordinate unit of Air Force Space Command located at Los Angeles AFB, California. The Space and Missile Systems Center (SMC) conducts development, procurement, deployment, and sustainment of United States military space and ballistic missile systems, including satellites and launch vehicles. Mr. Mulcahy researches and writes historical publications, conducts oral history interviews, and provides other historical products for SMC. He also provides historical information about SMC and its programs in response to requests from and within the Air Force, other federal agencies, and the general public. Mr. Mulcahy has been a historian at SMC since 2000, and has published numerous history-related magazine articles for commercial publications. Mr. Mulcahy is a retired member of the Army Reserve.

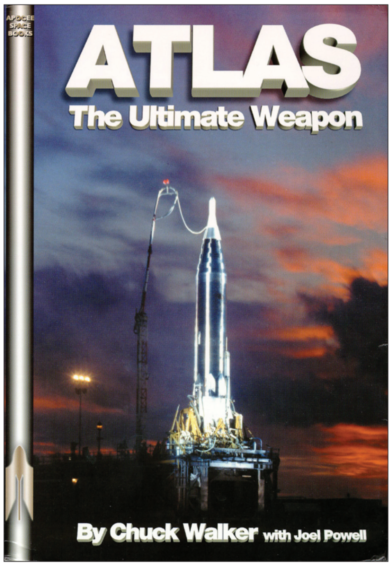
Book Review

Atlas: The Ultimate Weapon

Atlas: The Ultimate Weapon. By Chuck Walker with Joel Powell. Burlington, Ontario, Canada: Apogee Books [Collector's Guide Publishing, Inc.], 2005. Maps. Photographs. Illustrations. Tables. Appendices. Glossary. Index. Pp. 308. $29.95 Paperback ISBN: 1-894959-18-3

Acquisition of the Atlas Intercontinental Ballistic Missile (ICBM) remains among the most complex programs ever undertaken by the United States Air Force. It might come as a surprise, therefore, that few book-length studies have examined either development of the Atlas ICBM or its application as a space-launch vehicle. John Chapman's *Atlas: The Story of a Missile* (1960) was a thinly disguised promotional piece that barely skimmed the surface with respect to acquisition issues. Based on extensive research in an impressive variety of official sources, Edmund Beard's *Developing the ICBM: A Study in Bureaucratic Politics* (1976) and Jacob Neufeld's *Ballistic Missiles in the United States Air Force, 1945-1960* (1990) analyzed Atlas development from different government-focused, perspectives. John Lonnquest's doctoral dissertation, *The Face of Atlas: General Bernard Schriever and the Development of the Atlas Intercontinental Ballistic Missile, 1953-1960* (1996), again based largely on official sources, questioned whether we should attribute the Atlas program's success primarily to General Schriever's management skills and his application of the concurrency concept—simultaneous development and testing of the weapon system, training, and construction of operational bases.

With Chuck Walker's *Atlas: The Ultimate Weapon*, we have a refreshingly different perspective on Atlas acquisition. As head of the Atlas Test Planning Group for Convair-Astronautics (later General Dynamics) during 1953-1958 and as the company's Atlas Program Planning Control manager during 1958-1963, Walker scheduled and monitored all contracted work—design, procurement, testing, production, and base activation. Consequently, he came to know personally many of the corporate engineers responsible for managing the Atlas program, and he approached more than 30 of them to tell the story in their own words. After ten years of preparation, during which the author suffered a stroke and accepted editorial assistance from Atlas enthusiast Joel Powell, the "contractor's view" of the Atlas program is in print.



Largely through passages culled from interviews and woven editorially into a collective oral history, *Atlas: The Ultimate Weapon* delivers a passionate, sometimes humorous, always personal portrait of the trials, tribulations, and triumphs experienced by Convair employees assigned to the program. From the selection of test sites and construction of test facilities to static firings, early launches from Cape Canaveral, and activation of operational Atlas bases across the United States, this book records a wealth of information that might otherwise have been lost forever. To a degree achieved by no previous study, it puts human beings at the center of the technological struggle to acquire and use Atlas as both a weapon system and a space launcher. Where recollections after nearly 50 years differ, Walker carefully notes discrepancies; where memories are consistent, he uses them to put additional flesh on otherwise skeletal facts.

Walker draws several historically significant conclusions about why or how the Atlas program succeeded. Adequately enforced configuration and change control processes became vital to ensuring that Atlas met an operational target date set five years earlier. Although many at Convair initially questioned the need for Ramo-Wooldridge Corporation as system integrator for Atlas, they ultimately conceded the latter had made positive contributions. Despite some friction and occasional controversies, relations among Convair and its subcontractors, Ramo-Wooldridge, the Air Force, labor unions, and community leaders near Atlas operational bases remained cooperative from beginning to end. Implementation of concurrency posed its own set of challenges but proved invaluable to meeting deadlines. The Air Force's insistence on use of computerized PERT (Program Evaluation and Review Technique) charts for activation of operational sites helped prevent schedule slips. When it became apparent in late 1960 that launch procedures used during Atlas development were too complicated and too lengthy for the military's operational purposes, a nine-month "Golden Ram" program allowed Convair to fix the situation at the reasonably low cost of $13 million.

Unfortunately, Walker's book is weak in several important respects. It contains editorial and typographical errors that better proofreading might have caught. Despite references throughout the text to sources such as Neufeld's book, the in-house *Convairiety* newsletter, *Aviation Week*, and Senate hearings, Walker's text reveals a rather superficial use of sources beyond his interviews with former Convair employees. The absence of scholarly annotations and bibliographic references inhibits our understanding of the author's research methodology. Some might question why Walker failed to include the recollections of former Air Force officers, Ramo-Wooldridge employees, or Convair subcontractors who worked on Atlas, but that would have produced a more comprehensive set of perspectives than the author intended. Although it could have been more skillfully crafted, *Atlas: The Ultimate Weapon* nonetheless offers delightful, informative reading.

Reviewed by Dr. Rick W. Sturdevant, Deputy Command Historian, HQ Air Force Space Command

We are interested in what you think of ***High Frontier*** and request your feedback. We want to make this a useful product to each and every one of you as we move forward in the development of our space professionals and to stimulate intellectual thought. Please send your comments, inquiries and article submissions to: HQ AFSPC/PAI, High Frontier Journal, 150 Vandenberg St, Ste 1105, Peterson AFB CO 80914-4020, Telephone: (719) 554-3523, Fax: (719) 554-6013, Email: afspc.pai@peterson.af.mil, To subscribe: nsage@colsa.com

U.S. AIR FORCE

AIR FORCE SPACE COMMAND

AFSPC/PAI
150 Vandenberg St.
Ste 1105
Peterson AFB, CO 80914
Telephone: (719) 554-3523
Fax: (719) 554-6013

For more information on space professional development visit: www.peterson.af.mil/spacepro

Air & Space Power Journal: www.airpower.maxwell.af.mil/airchronicles/apje.html